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# A NASPAC-Based Analysis of the Delay and Cost Effects of the Dallas/Fort Worth Metroplex Plan



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October 1992

DOT/FAA/CT-TN92/21

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U.S. Department of Transportation
**Federal Aviation Administration**

Technical Center
Atlantic City International Airport, N.J. 08405

81 pgs.

## NOTICE

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Report No. DOT/FAA/CT-TN92/21

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October 1992

Prepared by
Department of Transportation
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Atlantic City International Airport, N.J. 08405

Pen and ink changes:

Add Report No. DOT/FAA/AOR-100-93/007

Cover
Technical Report Documentation Page, Block 1

Released December 1992

Technical Report Documentation Page

| | | |
|---|---|---|
| 1. Report No. DOT/FAA/CT-TN92/21 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle A NASPAC-Based Analysis of the Delay and Cost Effects of the Dallas/Fort Worth Metroplex Plan | | 5. Report Date October 1992 |
| | | 6. Performing Organization Code ACD-340 |
| 7. Author(s) Joseph M. Richie, Douglas Baart and Arthur Pomerantz(CTA) | | 8. Performing Organization Report No. DOT/FAA/CT-TN92/21 |
| 9. Performing Organization Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405 | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. F2006E |
| 12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Operations Research Service Washington, DC 20590 | | 13. Type of Report and Period Covered Technical Note September -July 1992 |
| | | 14. Sponsoring Agency Code AOR-100 |
| 15. Supplementary Notes | | |

16. Abstract

This technical note contains the findings and analysis of the effects of the Dallas/Fort Worth (DFW) Metroplex Plan on local and system-wide traffic delays. The National Airspace System Performance Analysis Capability (NASPAC) was used to perform this task, and calculates the local (DFW) and system-wide delays with and without the Metroplex Plan. Cost savings were derived using the cost of delay module based on these delays, on passenger cost, and on airline and aircraft specific cost. The results indicate that the plan will reduce delay in the years 1995, 2000, and 2005 at DFW and system-wide for all scenarios modeled. The Southwest Region will be using these results in its planning efforts to execute the Metroplex Plan.

| | |
|---|---|
| 17. Key Words Metroplex Plan NASPAC Operational Delay Passenger Delay | 18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161. |

| | | | |
|---|---|---|---|
| 19. Security Classif. (of this report) Unclassified | 20. Security Classif. (of this page) Unclassified | 21. No. of Pages 81 | 22. Price |

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENT

The authors thank Arturo Politano and Mike Flores, AOR-100 for their support. Joe Sinnott, Mike White, and Willie Weiss of MITRE provided details of previous related studies and other information necessary for the conduct of this study. Many thanks to the FAA Technical Center NASPAC team for a job well done.

The authors also acknowledge the support of the Southwest Regional Administrator, Mr. Clyde M. DeHart, Jr., and his Deputy, Mr. Jack Sasser, and the help of Ron Uhlenhaker, Quentin Ogilvie, and Allen Crocker of the DFW Metroplex Plan Program Office, ASW-1C, for their support in conducting this study.

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## EXECUTIVE SUMMARY


The Federal Aviation Administration's (FAA's) Southwest Region is increasing airport capacity and restructuring the airspace surrounding Dallas/Fort Worth (DFW) International Airport. The enhancements are designed to meet the traffic growth into the 21st century. This entire package of enhancements is known as the DFW Metroplex Plan.

This study was conducted to determine the effects of the DFW Metroplex Plan on local and system-wide air traffic performance. The National Airspace System Performance Analysis Capability (NASPAC) was used to simulate the essential elements of the plan and to estimate its impact on NAS performance. The NASPAC simulation calculated local (DFW) and system-wide delays with and without the Metroplex Plan. The cost savings estimates were derived from measuring the difference in delay with and without the plan in place and translating the delay into costs estimates. The baseline case for this study was developed using the Aviation System Capacity Plan by modifying it to assume that no improvements would be made at DFW, and scaling the Terminal Area Forecasts (TAF) for DFW for the no improvement case. Delay cost estimates were determined from a base of 1991 data on airline operating expenses.

This study was conducted at the FAA Technical Center by the Air Traffic Control (ATC) Technology Branch, ACD-340, under the sponsorship of the Operations Research Service, AOR-100. The analysis was performed at the request of the DFW Metroplex Air Traffic System Plan Program Office, ASW-1C.

Three different weather scenario days were used to capture the effects of weather typically observed for the entire year at DFW. These include one visual meteorological conditions (VMC) day where all 58 airports modeled, including DFW, were at or near maximum capacity. The second day was instrument meteorological conditions (IMC) at various airports throughout the country, with severe weather conditions at DFW for approximately 17 hours of the day. This day was referred to as IMC1 in the simulation. The third day was IMC at DFW for approximately 6 hours, and was referred to as IMC2 in the simulation. Four different time frames were simulated: a 1989 baseline case, as well as the years 1995, 2000, and 2005, with and without the proposed DFW improvements. In all the future year scenarios, the enhancements (for airports other than DFW) in the Aviation System Capacity Plan (ASCP) were assumed to be in place. The demand in all cases (except the 1989 baseline case) comes from the TAF.

<u>RESULTS</u>.

A comparison of the percent reductions in daily operational and passenger delays at DFW and system-wide with the Metroplex Plan in

place are given in tables E-1 and E-2, where "SCEN" stands for the word scenario:

TABLE E-1. PERCENT REDUCTION IN DAILY OPERATIONAL DELAY WITH DFW METROPLEX PLAN

| | 1995 | | 2000 | | 2005 | |
|---|---|---|---|---|---|---|
| SCEN | DFW | NAS | DFW | NAS | DFW | NAS |
| VMC | 65% | 11% | 84% | 17% | 82% | 19% |
| IMC1 | 80% | 18% | 93% | 22% | 91% | 18% |
| IMC2 | 80% | 10% | 90% | 14% | 91% | 11% |

TABLE E-2. PERCENT REDUCTION IN DAILY PASSENGER DELAY WITH DFW METROPLEX PLAN

| | 1995 | | 2000 | | 2005 | |
|---|---|---|---|---|---|---|
| SCEN | DFW | NAS | DFW | NAS | DFW | NAS |
| VMC | 48% | 4% | 89% | 19% | 80% | 16% |
| IMC1 | 82% | 17% | 93% | 24% | 89% | 17% |
| IMC2 | 82% | 9% | 88% | 16% | 85% | 13% |

The operational and passenger delay tables above show a large reduction in delay under all of the weather scenarios modeled. The reduction is attributed to the increase in capacity at DFW due to the Metroplex Plan. The maximum benefit occurs, as expected, under IMC1, the worst case scenario (17 hours IMC at DFW). The benefits diminish somewhat between 2000 and 2005 due to the increase in demand at DFW with no additional improvements modeled.

The results indicate that the Metroplex Plan will enhance the performance of operations at DFW, airports that share traffic with DFW, and the NAS as a whole by reducing delay. These benefits are evident even though the traffic demand steadily increases at DFW and the NAS for every year up to 2005. Traffic demand profiles were derived from the TAF.

The improvements are expected to provide monetary savings based on the reduction in operational and passenger delay at both the local

and system level. The annual savings in operational cost at DFW and system-wide by the year 2005 were estimated to be $202 and $313 million, respectively. Cumulative savings for the years 1995 - 2005 at DFW are $1.725 billion, and savings for the NAS are estimated to be $2.510 billion. These estimates are in 1991 dollars.

The annual savings in passenger cost at DFW and system-wide in 2005 were estimated at $377 and $705 million, respectively. Cumulative savings for years 1995 - 2005 at DFW were estimated at $2.751 billion, and savings for the entire system are $5.034 billion. Again, both estimates are in 1991 dollars.

The total annual savings at DFW and the NAS in the year 2005, including the operational and the passenger delays, are estimated to be $1.597 billion. Cumulative savings for years 1995 -2005 for DFW were estimated to be $4.476 billion, and savings for the entire system are expected to be $7.544 billion.

## 1. INTRODUCTION.

The Federal Aviation Administration's (FAA's) Southwest Region is increasing airport capacity and restructuring the airspace surrounding the Dallas/Fort Worth (DFW) International Airport. The enhancements are designed to meet the traffic growth into the 21st century. These enhancements include:

a. Two new runways: (1) 16R/34L located 5,800 feet west of 18R/36L, and (2) 16L/34R located 5,000 feet east of 17L/35R.

b. Two-thousand foot extensions to 18L and 17R.

c. Two new air traffic control (ATC) towers: one between 16R/34L and 18R/36L, the other between 17L/35R and 16L/34R.

d. New navigational aids (NAVAIDS) and radar sites installed to improve traffic flow.

e. Additional sectors created by dividing existing sectors.

f. Route capacity enhanced by restructuring the route system.

These enhancements are designed to relieve existing capacity problems of the en route airway system, terminal airspace constraints, military special operating areas, inefficient handling of high performance turboprop aircraft, and limited track capacity of the DFW Automated Radar Terminal System (ARTS) IIIA. This entire package of enhancements is known as the DFW Metroplex Plan.

To simulate the impacts of the Metroplex Plan, the National Airspace System Performance Analysis Capability (NASPAC) Simulation Modeling System (SMS) was used to measure throughput and delays at DFW and throughout the NAS. NASPAC is a tool used by the FAA to evaluate the performance of the National Airspace System (NAS). It is also used for strategic planning, for identifying bottlenecks in the system, and for evaluating alternative solutions to capacity and demand related issues.

### 1.1 BACKGROUND.

Air travel for the DFW International Airport and its surrounding airspace is projected to increase by as much as 100 percent by the year 2000 according to FAA Terminal Area Forecasts (TAF) [1]. In January 1987, a task force composed of representatives of the Fort Worth Center (ZFW), DFW Flight Service Station, DFW Terminal Radar Approach Control Facility (TRACON), and the Southwest Region convened to develop a plan for dealing with the projected traffic growth. The task force recommended that changes be made to DFW and to key satellite airports with control towers. The east satellite airports are Addison (ADS), Dallas Naval Air Station (NBE), Dallas Love (DAL), and Redbird (RBD). The west satellite airports with

towers are Fort Worth Meacham (FTW) and Carswell Air Force Base (FWH). Figure 1 shows the layout of the DFW area airports.

To meet projected demand, efforts are underway by the DFW Metroplex Plan Program Office to complete some of these vital enhancements at DFW by 1995. These enhancements will include the development of triple and quadruple simultaneous parallel Instrument Landing System (ILS) approaches, one new runway, expansion of the terminal control area, improvement to the arrival/departure system, and development of an independent high performance turboprop system.

Previous studies were performed on the effects of the DFW Metroplex Plan for the FAA and Southwest Region by the ATAC Corporation using SIMMOD [2], and MITRE using NASPAC [3,4]. The results show that implementing the DFW Metroplex Plan is expected to increase capacity, reduce delays, and have a positive impact on the local economy. In addition, according to the earlier NASPAC studies, a reduction in delay would occur at other airports that share traffic with DFW and in the NAS as a whole. Those studies, however, only used a 1995 future demand and did not estimate delay savings in monetary terms.

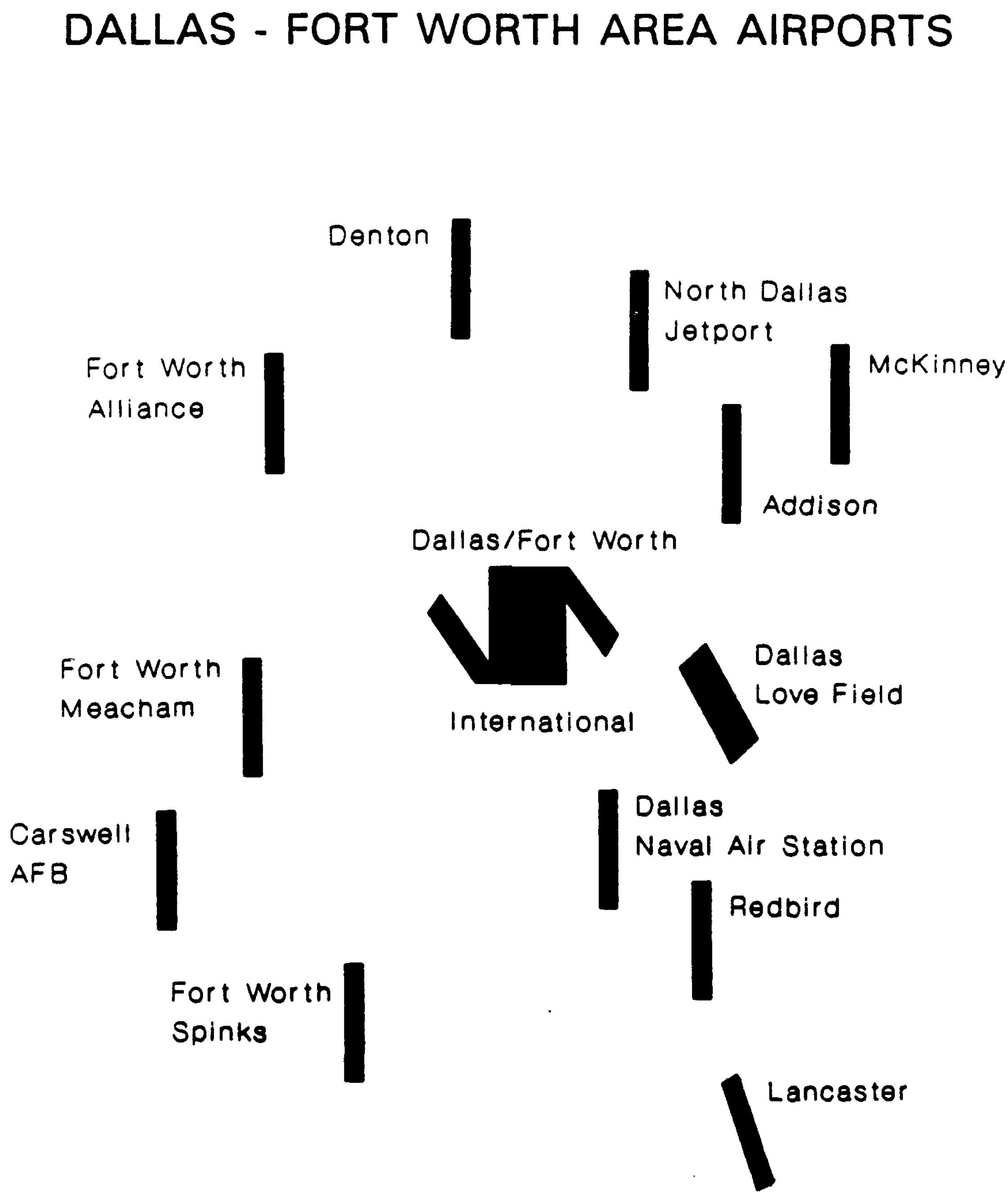
## 1.2 STUDY PURPOSE AND OBJECTIVES.

The purpose of the study is to evaluate the effects that the Metroplex plan has on future delay and throughput at DFW and the entire NAS, and to estimate the associated cost savings. This was done by simulating operations at DFW using new capacity estimates and a 2005 traffic demand. The increase in capacity can be realized with the addition of two new runways. Arrival and departure fixes and key source/sink airports were included in the analysis as a means of accumulating additional operational delay.

This study builds upon the previous NASPAC study of the DFW plan [3,4] and uses many of the same modeling techniques. This study, however, simulates years 2000 and 2005 scenarios, whereas, the previous NASPAC study projected only to year 1995. In addition, this study estimated savings in delay costs by using a program which was recently developed to address cost of delay [5]. The 1992 study also employs more recent Terminal Area Forecasts (TAF) and capacity data and takes advantage of recent refinements to NASPAC software. The software modifications include improved calculation of en route flight times, stochastic modeling of pushback delays, and changes to the EDCT program. These modifications are designed to improve the fidelity of the model.

## 2. TECHNICAL APPROACH.

This section provides a brief overview of the NASPAC model and describes the system metrics, scenario definitions, and the assumptions used in this study.




**Provided by the Metroplex Plan Program Office, ASW-1C**

**FIGURE 1. DFW AREA AIRPORTS**

## 2.1 NASPAC SIMULATION MODEL.

NASPAC is a tool used by the FAA to analyze the impacts of proposed operational and capital improvements on the performance of the NAS. It is an event-step discrete simulation model that tracks the progress of each aircraft as they compete for and use ATC resources. NASPAC simulates system-wide performance and provides a quantitative base for decision making related to system improvements and management. The model supports strategic planning by identifying air traffic flow congestion problems and examining solutions to capacity and demand related issues. NASPAC has been used to analyze the interactions between components of the airspace system, and how the system reacts to projected demand and capacity changes.

NASPAC is a macro model used to estimate system-wide impacts of an ATC proposed change. Traffic profiles consist of scheduled and unscheduled arrivals and departures for 58 major airports. Scheduled demand is derived from the Official Airline Guide (OAG) and is used for predicting future growth. Unscheduled demand is derived from daily and hourly distributions taken from real world data (tower count). When using these distributions, the model randomly selects unscheduled flights for inclusion in the hourly airport arrival and departure demand. The projected traffic growth is provided by the TAF.

Among the major descriptive parameters used by the model is airport acceptance rates (AAR). Two servers model airports: one handles arrivals and the other departures. Each modeled airport requires two sets of values. The first represents an arrival priority strategy. It consists of the maximum arrival rate (arr) and its corresponding minimum departure rate (mdp). The second set of capacities represents a departure priority strategy. It consists of a maximum departure rate (dep) and minimum arrival rate (mar). When there is a high demand for arrivals and a low demand for departures, an arrival priority is used. The opposite will hold true when there is a high request for departures and a low request for arrivals. The simulation uses the queue length to measure the demand. If the demand is between two extremes, the model calculates the ratio of the queue length. This ratio determines the values on the capacity curve at which the servers operate [1,6].

## 2.2 NASPAC SIMULATION SYSTEM MEASURES.

NASPAC's key metric of performance is delay. The model calculates delay for each flight in the system, and aggregates throughput and delay for each of the 58 modeled airports. In addition, arrival and departure fixes, en route sectors, and restrictions are other modeled resources that measure delay. System metrics encompass every type of delay measured in the model.

The two types of delay that the model records are technical (operational) and effective (passenger) delay. Technical delay is the type of delay absorbed by aircraft as they wait to use ATC resources such as runways, fixes, etc. Passenger delay is the difference between the scheduled and actual arrival times recorded in the simulation, regardless of cause. An aircraft that arrives on time and accumulates no passenger delay can still accrue operational delay.

Metrics used in this study to analyze the impacts of the Metroplex Plan on DFW and the NAS are:

a. System-wide operational delay

b. System-wide passenger delay

c. Operational delay at DFW

d. Passenger delay at DFW

e. Cost of delay at DFW and system-wide.

These metrics are used to gauge the impacts of the Metroplex Plan has on DFW and the NAS as a whole. The NASPAC Cost of Delay Module was used to provide monetary values for the delay recorded in the simulation.

## 2.3 SCENARIO DEFINITIONS.

Scenarios used in this study are defined by several variables such as weather, airspace geometry, time-frame, capacity, and demand. The study uses three different weather scenario days. The first day is based on weather observed on March 22, 1989, where most of the country was under Visual Meteorological Conditions (VMC). Under these conditions, all airports, including DFW, are at or near their maximum capacity. The second day represents Instrument Meteorological Conditions (IMC). This day is denoted as IMC1. It has weather similar to that on February 14, 1989, where the capacity of some airports are reduced due to weather conditions. Under this scenario, the weather at DFW was under an IMC condition for about 17 hours. The third day represents weather similar to the weather that was observed on March 2, 1989. The weather at DFW was under IMC conditions for approximately 6 hours. Table 1 shows the 58 modeled airports with capacity-related improvements and hours in IMC for scenario days. These capacity-related improvements are assumed to be in place by 1995. The ceiling and visibility for both VMC and IMC at DFW are defined in section 2.4, "Assumptions and Caveats."

Capacity estimates at DFW and the other modeled airports are influenced by weather. This is due to the runway configuration enforced during periods of bad weather. VMC provide the maximum

TABLE 1. WEATHER CONDITIONS AND PROPOSED IMPROVEMENTS AT THE 58 MODELED AIRPORTS

| MODELED AIRPORT | AIRPORT CODE | ASSUMED CAPACITY-RELATED IMPROVEMENTS BY 1995* | HOURS IN IMC IMC1 DAY | HOURS IN IMC IMC2 DAY |
|---|---|---|---|---|
| Albuquerque | ABQ | | | |
| Atlanta Hartsfield | ATL | New parallel commuter runway | 1.5 | 8.5 |
| Baltimore | BWI | New parallel rwy; runway extension | | |
| Boston Logan | BOS | | | |
| Burbank | BUR | | | 7.0 |
| Charlotte | CLT | New independent parallel runway | | |
| Chicago Midway | MDW | | | 15.0 |
| Chicago O'Hare | ORD | | | 16.0 |
| Cincinnati | CVG | New independent parallel runway | 24.0 | |
| Cleveland Hopkins | CLE | | 2.5 | 1.5 |
| Dallas Love | DAL | | 17.5 | 15.0 |
| Dallas-Fort Worth | DFW | New parallel runway | 17.5 | 6.0 |
| Dayton | DAY | | 11.0 | |
| Denver | DEN | New airport | 13.0 | 24.0 |
| Detroit Metro | DTW | New parallel and crosswind runways | | 10.0 |
| Fort Lauderdale | FLL | Runway extensions | | 4.0 |
| Houston Hobby | HOU | | 12.5 | 24.0 |
| Houston Intercontinental | IAH | New parallel runway | | 15.0 |
| Indianapolis | IND | New parallel runway | | |
| Islip | ISP | | 17.0 | |
| Kansas City | MCI | Two new runways: one independent | 3.0 | |
| Las Vegas | LAS | New parallel runway | | |
| Long Beach | LGB | | | 9.0 |
| Los Angeles | LAX | | | 13.0 |
| Louisville | SDF | Two new independent parallels | 24.0 | |
| Memphis | MEM | New parallel runway | 23.0 | |
| Miami | MIA | | | 3.0 |
| Milwaukee Mitchell | MKE | | 1.5 | 12.0 |
| Minneapolis-St. Paul | MSP | | | 8.0 |
| Nashville | BNA | New parallel runway | 20.0 | |

* These are improvements listed in the Airport Capacity Enhancement Plan (FAA 1989a) that were estimated to provide capacity increases on the modeled scenario days

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TABLE 1. WEATHER CONDITIONS AND PROPOSED IMPROVEMENTS AT THE 58 MODELED AIRPORTS (CONTINUED)

| MODELED AIRPORT | AIRPORT CODE | ASSUMED CAPACITY-RELATED IMPROVEMENTS BY 1995* | HOURS IN IMC IMC1 DAY | HOURS IN IMC IMC2 DAY |
|---|---|---|---|---|
| New Orleans | MSY | Two new independent parallels | | 3.0 |
| New York Kennedy | JFK | | 17.0 | |
| New York La Guardia | LGA | | 1.5 | |
| Newark | EWR | | 5.5 | |
| Oakland | OAK | | | 3.0 |
| Ontario | ONT | | 19.0 | 17.0 |
| Orlando | MCO | Two new dependent parallel runways | | 14.0 |
| Philadelphia | PHL | New independent parallel runway | 0.5 | |
| Phoenix | PHX | New close parallel runway | | |
| Pittsburgh | PIT | | 16.0 | |
| Portland (OR) | PDX | | | 4.0 |
| Raleigh Durham | RDU | New independent parallel runway | | |
| St. Louis | STL | | 3.0 | |
| Salt Lake City | SLC | New independent parallel runway | 2.0 | 4.0 |
| San Antonio | SAT | | 8.0 | 12.0 |
| San Diego | SAN | | | 14.0 |
| San Francisco | SFO | | | 2.0 |
| San Jose | SJC | | | |
| Santa Ana | SNA | | | 5.0 |
| Seattle Tacoma | SEA | | 8.0 | 11.0 |
| Syracuse | SYR | New independent GA runway | 5.0 | 3.0 |
| Tampa | TPA | New close parallel runway | | 11.0 |
| Teterboro | TEB | | 2.0 | |
| Washington Dulles | IAD | New parallel and crosswind runways | 5.5 | |
| Washington National | DCA | | 4.0 | |
| West Palm Beach | PBI | | | |
| White Plains | HPN | | 5.0 | |
| Windsor Locks Bradley | BDL | | 4.5 | |

* These are improvements listed in the Airport Capacity Enhancement Plan (FAA, 1989a) that were estimated to provide capacity increases on the modeled scenario days

capacity, mainly because of the use of visual approach and visual separation. The capacity decreases under IMC because arriving aircraft must use instrument approaches. This results in the inability of the arriving traffic to run simultaneous approaches.

The Metroplex Program Office, ASW-1C, requested that the same scenario days in the earlier NASPAC studies be used in this study [3,4]. Three stochastic runs of each scenario were processed to capture the stochastic elements for each of the scenarios modeled.

The definition of the scenarios also includes the selection of a time frame and the improvements studied. The following seven cases were analyzed :

a. 1989 with present DFW demand and present capacity (baseline).

b. 1995 with future demand and present capacity (no improvements) at DFW.

c. 1995 with future demand and Metroplex Plan improvements (one new runway).

d. 2000 with future demand and present capacity (no improvements) at DFW.

e. 2000 with future demand and Metroplex Plan Improvements (two new runways).

f. 2005 with future demand and present capacity (no improvements) at DFW.

g. 2005 with future demand and Metroplex Plan Improvements (two new runways).

The additional demand for the improvement cases reflect higher capacities generated by the addition of the two new runways.

Table 2 represents the design of the study in a 3 X 7 matrix. The left hand column represents the weather days modeled, and the column headings indicate the years modeled with and without the improvements.

These improvements are modeled by changing the airport capacity at DFW, and by revising the arrival and departure fix attributes.

## 2.4 ASSUMPTIONS AND CAVEATS.

Standard VMC conditions at DFW are defined by a ceiling of 3,500 feet or higher, and visibility of 5 miles or greater with five runways configured for north or south traffic flows. Under IMC, four runways are used for north or south traffic flows, the ceiling

TABLE 2. SCENARIO STRUCTURE

| SCEN | 1989 BL | 1995 No Imp | 1995 1 Rwy | 2000 No Imp | 2000 2 Rwys | 2005 No Imp | 2005 2 Rwys |
|---|---|---|---|---|---|---|---|
| VMC | X | X | X | X | X | X | X |
| IMC1 | X | X | X | X | X | X | X |
| IMC2 | X | X | X | X | X | X | X |

Note: The X's represent the details for each scenario, BL denotes baseline, and Scen denotes scenario.

is between 200 and 3,500 feet, and visibility is between 1.5 and 5 miles. The ceiling and visibility at any given airport determines the capacity for that airport. For example, at DFW under VMC the maximum capacity (arrival/departure) is 296 aircraft. This is based on DFW acceptance rate of 160; that is, the number of arriving aircraft accepted in 1 hour. Under IMC, the maximum capacity is 180 aircraft. This is based on an acceptance rate of 100 aircraft per hour.

The EDCT's used in the simulation are estimates based on the model's acceptance rate.

For all future-year configurations, planned improvements at major airports other than DFW are assumed to be in place. Future demand and capacity projections are based on this assumption. It is assumed that the new Denver (DVX) Airport will be in place by 1995. The latest TAF data were used in the analysis, FY 1991 - 2005 [1].

The second release (R2) of NASPAC was used to perform this study. Release 1 (R1) of NASPAC was used in the two DFW studies conducted by MITRE [3,4].

While the model used included a ground delay program, this study did not model flight cancellations or flow-control slot swapping. NASPAC does not reroute or divert aircraft to satellite airports when delay becomes excessive, nor does it address issues unrelated to capacity.

NASPAC contains stochastic elements that cause slight differences in results between runs with otherwise identical input. To capture the stability of these elements, the three model runs were averaged.

## 3. METHODOLOGY.

This section describes the procedural details of the study. The sources of capacity and future demand data are given along with the capacity values used for DFW airport. The method of modeling changes to the terminal airspace is described, followed by a discussion of the cost estimation used.

### 3.1 CAPACITY.

The capacity values used in this study were provided by the DFW Metroplex Air Traffic System Program Office, ASW-1C. These values are based on discussions with the DFW tower, ZFW, DFW TRACON and other experts in the field who control DFW traffic on a daily basis. The 1988 FAA Engineered Performance Standards (EPS) were also used as a reference. Tables 3 and 4 show the capacity values used in the simulation under VMC and IMC. These values represent the maximum, minimum, and 50/50 mix of the hourly departure and arrival rates at DFW. The minimum departure capacity is the hourly departure rate when arrivals are given highest priority (arrival priority). Conversely, minimum arrival capacity exist when departures are at their maximum levels (departure priority). The minimum service time between successive arrival and departure are determined from these hourly rates and the queue lengths of arrivals and departures. The inverse of these service times are the capacity values that are furnished for each of the 58 modeled airports. The principal delay metric that accumulates in the model is at the airports where aircraft compete for runway usage.

### 3.2 FUTURE DEMAND FORECASTS AND INPUT DATA.

The demand used in the model consists of unscheduled demand from historical data (tower counts at modeled airports) and scheduled demand derived from the OAG. The 1989 demand levels were used as a baseline for predicting future demand. The projected growth at DFW and other airports in the NAS were provided by the FAA's Office Of Aviation Policy and Plans (APO) through the TAF [1] 1990 - 2005. This file consists of air carrier and general aviation operations.

The model also accounts for ground delays issued by Central Flow Control Facility (CFCF). These are due to adverse weather conditions at the destination airport or any en route restrictions. The Estimated Departure Clearance Times (EDCT) are computed and appended to the schedule for each affected flight.

The unscheduled demand is described by daily and hourly distributions taken from real world data (tower count). The primary source of the Instruments Flight Rules (IFR) General Aviation (GA) and military flights is the "Host_Z" data. The data are collected by the Air Route Traffic Control Center's (ARTCC's) and sent to CFCF by satellites for each flight in the system. The weather data

used in the model was taken from surface observations at all of the modeled airports.

TABLE 3. DFW CAPACITY VALUES UNDER VMC

| WX & Improvements | arr Priority | dep Priority | 50/50 |
|---|---|---|---|
| VMC No Improvement | Max A 92<br>Min D 89 | Min A 78<br>Max D 109 | A 90<br>D 90 |
| VMC with 1 New Runway | Max A 122<br>Min D 118 | Min A 104<br>Max D 145 | A 118<br>A 118 |
| VMC with 2 New Runways | Max A 160<br>Min D 136 | Min A 118<br>Max D 178 | A 142<br>D 142 |

TABLE 4. DFW CAPACITY VALUES UNDER IMC

| WX & Improvements | arr Priority | dep Priority | 50/50 |
|---|---|---|---|
| IMC No Improvement | Max A 66<br>Min D 60 | Min A 60<br>Max D 85 | A 60<br>D 60 |
| IMC with 1 New Runway | Max A 90<br>Min D 75 | Min A 90<br>Max D 111 | A 90<br>A 90 |
| IMC with 2 New Runways | Max A 120<br>Min D 104 | Min A 118<br>Max D 178 | A 110<br>D 110 |

The TAF projections for future demand at DFW (and other airports) take into account the increased in capacity that accompany airport expansion. For the cases in which future years were simulated without the DFW improvements, the demand was scaled back to compensate for growth attributable to the plan itself. We examined growth projections for other airports in the region with no planned improvements and scaled back DFW traffic accordingly. Scaling back the demand will yield a more conservative estimate of the effects of the plan. The same approach was taken for the previous NASPAC study of DFW.

Figure 2 shows the forecast number of daily operations at DFW. The growth between 1991 and 2005 with the improvements in place was forecasted by the TAF (FY 1991 - 2005) [1]. The growth between 1989 and 2005 without the Metroplex Plan is based on the TAF growth data.

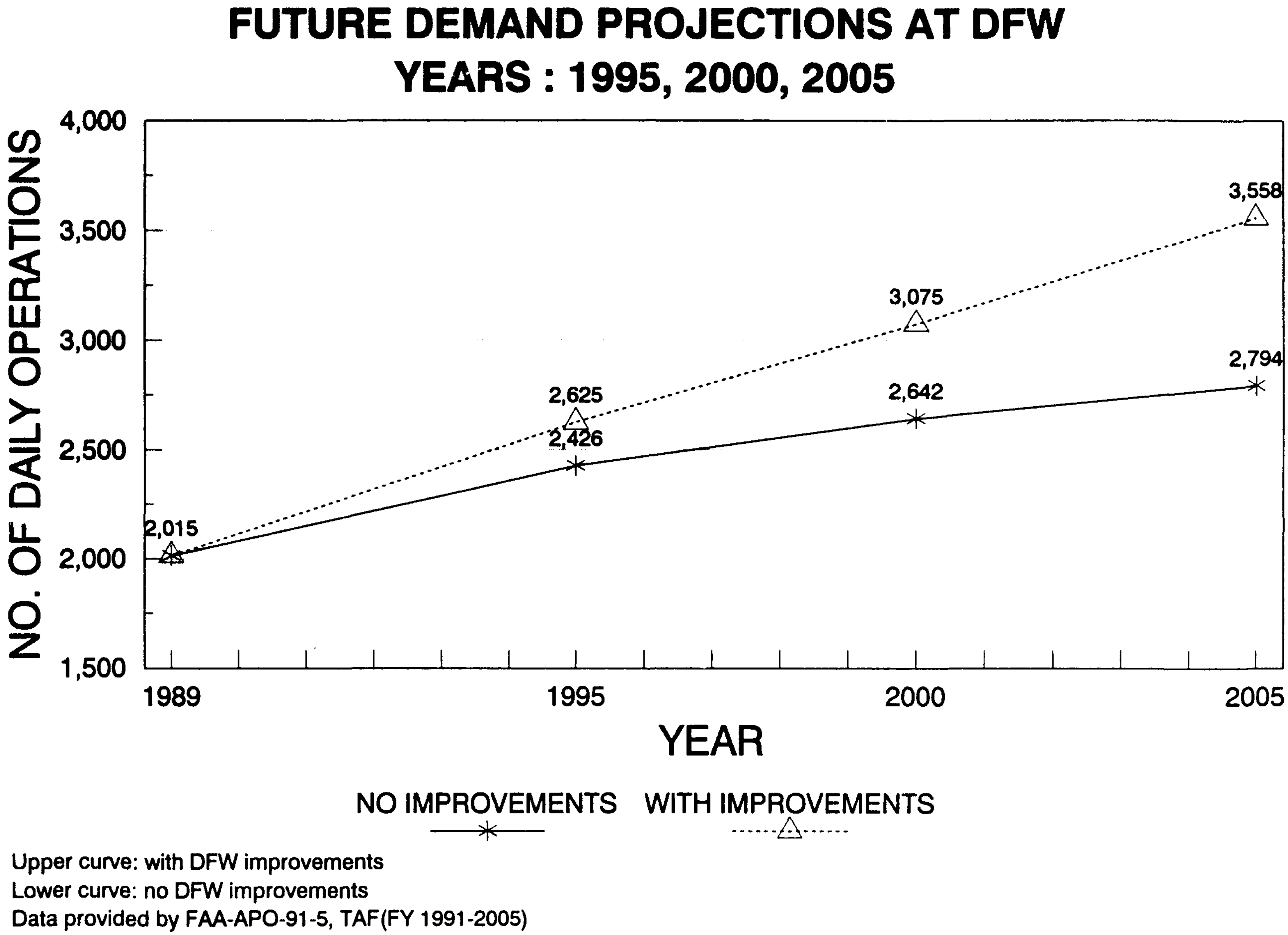



FIGURE 2. FORECASTED NUMBER OF DAILY OPERATIONS AT DFW

These values represent an estimated 20 percent growth from 1989 to 1995, 31 percent growth from 1989 to 2000, and 39 percent growth from 1989 to 2005 without the Metroplex Plan. The growth with the Metroplex Plan in place is estimated to be at 30 percent between 1989 and 1995, 53 percent between 1989 and 2000, and at 77 percent between 1989 and 2005.

In 1995, with one new runway in place, there will be an estimated increase in the traffic of 199 operations per day or approximately 8 percent. In the year 2000, with two runways in place, there will be an estimated increase in traffic of 433 operations per day or approximately 17 percent. In 2005 with two runways in place, there will be an estimated increase in traffic of 764 operations per day or approximately 27 percent.

## 3.3 RESTRUCTURING DFW AIRSPACE.

In addition to expanding DFW airport capacity, the Metroplex Plan calls for modifications to the surrounding airspace. More arrival and departure streams will be added, sectors will be restructured, and new navigational and surveillance aids installed.

Currently, arrival traffic is routed from en route airspace over one of four cornerposts. The cornerposts are Bridgeport (BPR) at the northeast corner, Blue Ridge (BUJ) at the northwest corner, Scurry (SCY) at the southeast corner, and Acton (AQN) at the southwest corner. These cornerposts are located approximately 42 nautical miles (nmi) from the center of the DFW terminal airspace. Departing aircraft are directed over four gates located between the cornerposts.

Under the Metroplex Plan, the terminal airspace will be expanded by relocating the existing cornerposts 16 nmi outward. This feature was not modeled since it was considered insignificant at the level of detail that the model could address. It was determined that the small change in the capacity figures would not significantly alter the results. The new design adds an additional parallel arrival stream to DFW over each of the four cornerposts. A parallel arrival stream for satellite airports over each cornerpost is also planned, resulting in one stream for east satellite arrivals and one for west satellites for each fix.

To model the arrival stream changes, an additional pseudo-fix was added at each cornerpost, representing the additional parallel stream for the satellites. (In the NASPAC model, multiple "fixes" may be located at the same latitude/longitude, but at different altitudes.) The main and parallel streams were not separated in the model, since the distance was not significant at the level of detail at which NASPAC operates. The additional fix was given the same capacity as the old parallel fix. The NASPAC database contains east and west satellite airports. The additional parallel

arrival stream to DFW at each cornerpost was modeled by doubling the capacity of one of the existing fixes.

Presently, three departure streams between the cornerposts are used by jet aircraft to the east, as well as three streams to the west and to the north. Two streams exist for aircraft departing south. These are to be replaced by four streams in each direction. Additional departure streams were modeled by increasing the capacities of the existing fixes proportionate to the increase in the number of streams.

Other airspace changes, while operationally significant, were not included in the study. NASPAC, being a system-wide simulation, does not model terminal airspace explicitly. Therefore, some planned modifications either could not be represented in the NASPAC model or were unlikely to have any effect on the results of the simulation. The approach used in modeling the airspace changes were essentially the same used in the previous NASPAC study [3].

### 3.4 EVALUATION OF DELAY COST.

The evaluation of the DFW Metroplex Plan focused on the monetary savings that could be realized with the addition of two new runways. These estimates were determined by using the Cost of Delay Module that was recently developed and incorporated into the latest release of the NASPAC model. The cost of delay module translates delay into cost based on operational and passenger delay costs for 1991. These savings at DFW are attributable to the reduction in delay from the added airport capacity. Comparisons were made between those scenarios which reflect the added capacity at the airport and those scenarios in which capacity remained the same.

The cost of delay module uses the latest data (last quarter of 1991) acquired from the Office of Airline Statistics (APO-200) as a means of determining operational and passenger costs. These costs include crew salaries, maintenance, fuel, equipment, depreciation, and amortization and are reported by the airlines on a quarterly basis to the Department of Transportation's (DOT's) Office of Aviation Statistics (Form 41). The data are aggregated by airlines and aircraft types and is used as a reference for the cost of delay module. This information is divided into airborne and ground costs for each airline and aircraft type in which cost information is reported. Passenger cost estimates were derived by using an FAA endorsed constant of $39.50, provided by the Office of Aviation Statistics (APO-200), multiplied by the hourly delay absorbed by all of the passengers aboard the flight. The estimated number of passengers aboard each flight is a function of aircraft type. This information was also provided by APO-200.

The NASPAC model produces a delay trace file for every simulation run. This file contains information pertaining to the delay (delay

type, time of delay, where the delay occurred, and a tail number which uniquely defines the aircraft carrier and aircraft type). This file is used to identify the carrier, aircraft type, and the magnitude of the delay that was simulated. The module defines the type of delay (airborne, ground, or passenger) and references the appropriate cost of that delay from an operational cost database based on the carrier and aircraft type. Operational airborne, operational ground, and passenger delays are treated as separate entities, each contributing to the total delay cost accumulated in the simulation. For example, if American Airlines flight 2234 type B-727 experiences an airport arrival delay of 3 minutes, the module will define the operational cost of an airborne delay for American Airlines type B-727 and multiply that number by 3. This is done for every type of operational delay occurring during the simulation. A report file is generated from the cost module summarizing cost estimates by delay type, air carrier, general aviation, and military operations.

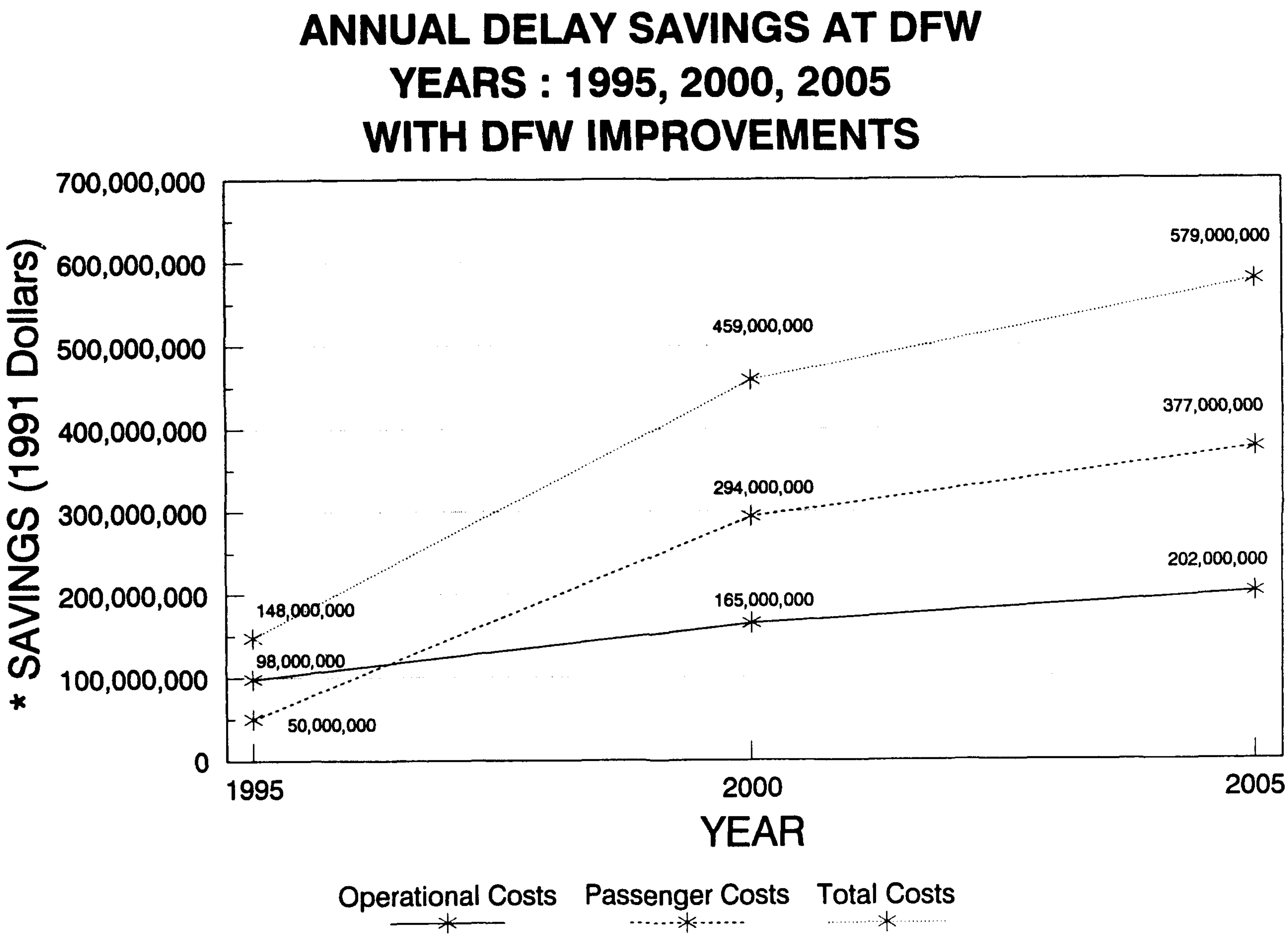
To calculate the annual delay cost, it was assumed that VMC occurs 80 percent of the time, IMC1 occurs 10 percent of the time, and IMC2 occurs 10 percent of the time. These percentages were applied to the delay costs for each of the scenarios as a means of estimating annual delay costs. These percentages were derived from historical data describing annual weather patterns. Linear interpolation between the years 1995, 2000, and 2005 was preformed to estimate the cost savings over a 10-year period. Figure 3 shows the annual savings at DFW with the Metroplex Plan; figure 4 shows the annual savings system wide with the Metroplex Plan. The savings are assumed to continue to increase linearly in both figures.

## 4. RESULTS.

(Additional figures are presented in appendix A.)

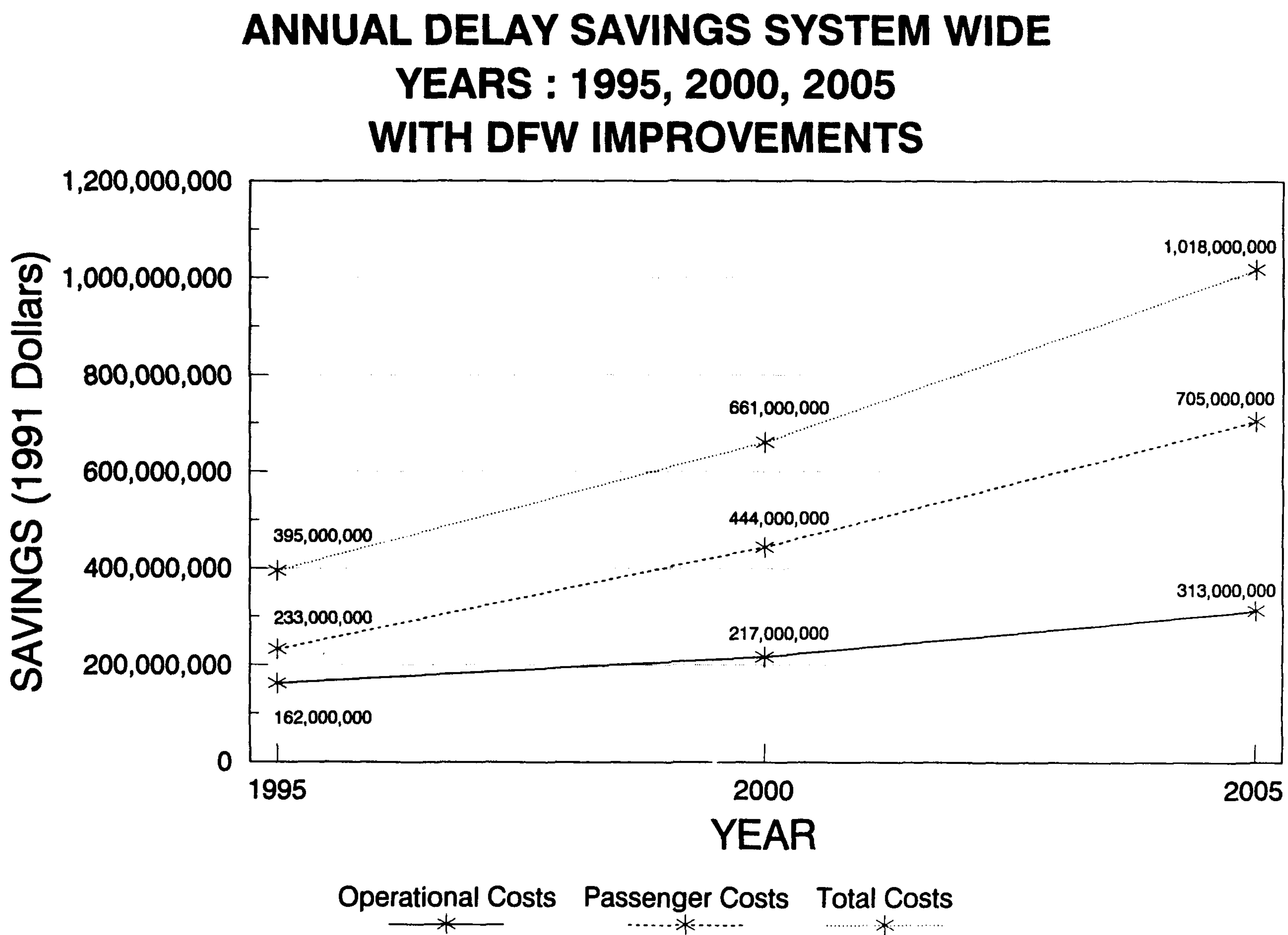
### 4.1 DFW DELAYS.

Table 5 shows the total minutes of operational (technical) delay at DFW for each scenario. Simulation results for DFW represent delays incurred at the airport only and do not include delays in the surrounding airspace. Unless otherwise specified, operational delay includes airport departure and arrival delay. With part of the plan in place by 1995, the delays are smaller than in the baseline year. The year 2000 scenario resulted in a further decrease in delay due to the implementation of a second runway. In the year 2005, there is a slight rise in operational delay from the levels that were observed in the year 2000. This is because no further improvements are modeled after 2000, but the demand continues to increase. The delays observed for 2005 with the airport expansion modeled, however, are still below the 1989 baseline levels.




Note: Savings are assumed to increase linearly

FIGURE 3. ANNUAL SAVINGS AT DFW WITH PLAN




Note: Savings are assumed to increase linearly

FIGURE 4. ANNUAL SAVINGS SYSTEM-WIDE WITH PLAN

TABLE 5. OPERATIONAL DELAY AT DFW

Total Minutes of Operational Delay at DFW

| SCEN | 1989 BL | 1995 No Imp | 1995 1 Rwy | 2000 No Imp | 2000 2 Rwys | 2005 No Imp | 2005 2 Rwys |
|---|---|---|---|---|---|---|---|
| VMC | 8,500 | 13,800 | 4,800 | 19,000 | 3,000 | 26,700 | 4,900 |
| IMC1 | 17,400 | 70,700 | 14,000 | 128,700 | 8,400 | 149,300 | 13,900 |
| IMC2 | 16,700 | 43,700 | 8,900 | 80,300 | 8,200 | 120,900 | 11,000 |

Without the Metroplex Plan, the operational delay at DFW was projected to increase significantly by the percentages that are shown in table 6. As expected, the increase in delay is greatest on the day which experienced the worst weather at DFW -- the IMC1 day.

TABLE 6. PERCENT INCREASE IN OPERATIONAL DELAY AT DFW WITHOUT THE PLAN

Percent Increase in Daily Operational Delay at DFW with No DFW Improvements

| SCEN | 1995 | 2000 | 2005 |
|---|---|---|---|
| VMC | 62% | 124% | 214% |
| IMC1 | 306% | 640% | 758% |
| IMC2 | 162% | 381% | 624% |

With the Metroplex Plan implemented, the results of the simulation has shown that operational delay at DFW airport would be reduced. The percent reduction is illustrated in figure 5. The reduction, in absolute numbers, is much greater on the IMC days than on the all-VMC days. This is to be expected, since the overall delay levels are higher on the IMC days. As a percentage of the overall delay, however, the VMC day shows delay reductions in the same range. The airport improvements substantially reduce delays in all three types of weather scenarios tested: an all VMC day, a moderate IMC day at DFW, and a severe (17 hours) IMC day at DFW.

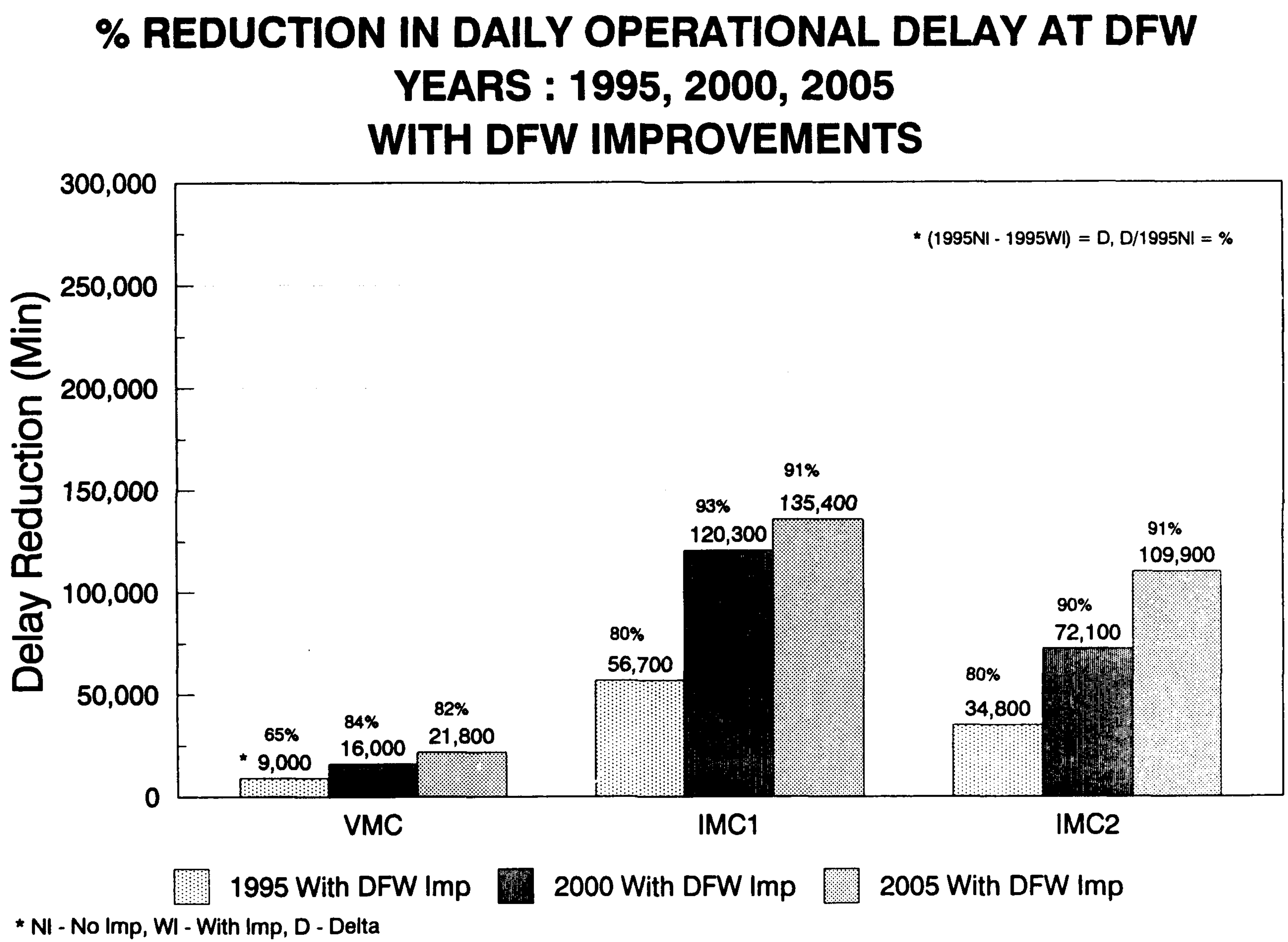



FIGURE 5. PERCENT REDUCTION IN OPERATIONAL DELAY AT DFW WITH PLAN

Table 7 shows the daily average minutes of operational delay at DFW for the time frame modeled, where the "NI" denotes "no improvements" and "WI" denotes "with improvements." The operational delay has shown significant reductions with the plan.

TABLE 7. AVERAGE OPERATIONAL DELAY AT DFW

Daily Average Minutes of Operational Delay at DFW with and with No DFW Improvements

| SCEN | 1989 | 1995 NI | 1995 WI | 2000 NI | 2000 WI | 2005 NI | 2005 WI |
|---|---|---|---|---|---|---|---|
| VMC | 4.25 | 5.75 | 1.85 | 7.25 | 0.95 | 9.60 | 1.40 |
| IMC1 | 8.51 | 29.20 | 5.20 | 48.65 | 2.75 | 53.50 | 3.90 |
| IMC2 | 8.02 | 18.05 | 3.40 | 30.35 | 2.70 | 43.25 | 3.10 |

Table 8 shows the operational delay savings at DFW airport due to the Metroplex Plan.

TABLE 8. ANNUAL SAVINGS AT DFW WITH THE PLAN

Annual Operational Delay Savings at DFW (in millions) with DFW Improvements

| 1995 | 2000 | 2005 |
|---|---|---|
| $98 | $165 | $202 |

Table 9 shows the total minutes of passenger (effective arrival) delay at DFW for all scenarios.

The simulation results indicate that without the Metroplex Plan, the passenger delay will increase. These percentages are shown in table 10. This increase occurs despite the scaling back of demand that was estimated from the TAF. If demand were not scaled back, the projected increase in both passenger and operational delay would be higher.

With the Metroplex Plan implemented, the passenger delay at DFW shows a reduction as indicated in figure 6. Figure 5 illustrates reduction in passenger delay.

TABLE 9. PASSENGER DELAY AT DFW

Total Minutes of Passenger Delay at DFW
(at Gate)

| SCEN | 1989 BL | 1995 No Imp | 1995 1 Rwy | 2000 No Imp | 2000 2 Rwys | 2005 No Imp | 2005 2 Rwys |
|---|---|---|---|---|---|---|---|
| VMC | 3,600 | 6,600 | 3,400 | 29,000 | 3,400 | 36,500 | 7,400 |
| IMC1 | 9,600 | 47,600 | 8,400 | 96,600 | 6,700 | 117,300 | 13,400 |
| IMC2 | 20,600 | 42,900 | 7,700 | 78,000 | 9,000 | 121,700 | 18,700 |

TABLE 10. PERCENT INCREASE IN PASSENGER DELAY AT DFW WITHOUT THE PLAN

Percent Increase in Daily Passenger Delay at DFW
with No DFW Improvements

| SCEN | 1995 | 2000 | 2005 |
|---|---|---|---|
| VMC | 83% | 731% | 914% |
| IMC1 | 396% | 906% | 1,122% |
| IMC2 | 108% | 279% | 491% |

Table 11 shows the daily average minutes of passenger delay at DFW for a particular time frame, where the "NI" denotes "the no improvements" case and "WI" denotes "with improvements." The reduction in average passenger delay is attributed to the Metroplex Plan.

The reduction in the passenger delay due to the Metroplex Plan are shown in table 12. Passenger delay savings were computed using an FAA endorsed hourly cost estimate of $39.50 per hour.

4.2 NAS WIDE DELAYS.

Table 13 shows the estimated total system-wide operational (technical) delay in minutes for all scenario days and modeled time frames. These values are the results of simulation for the baseline (1989), and future years with and without the Metroplex Plan. Delays increase over time with or without the DFW Metroplex

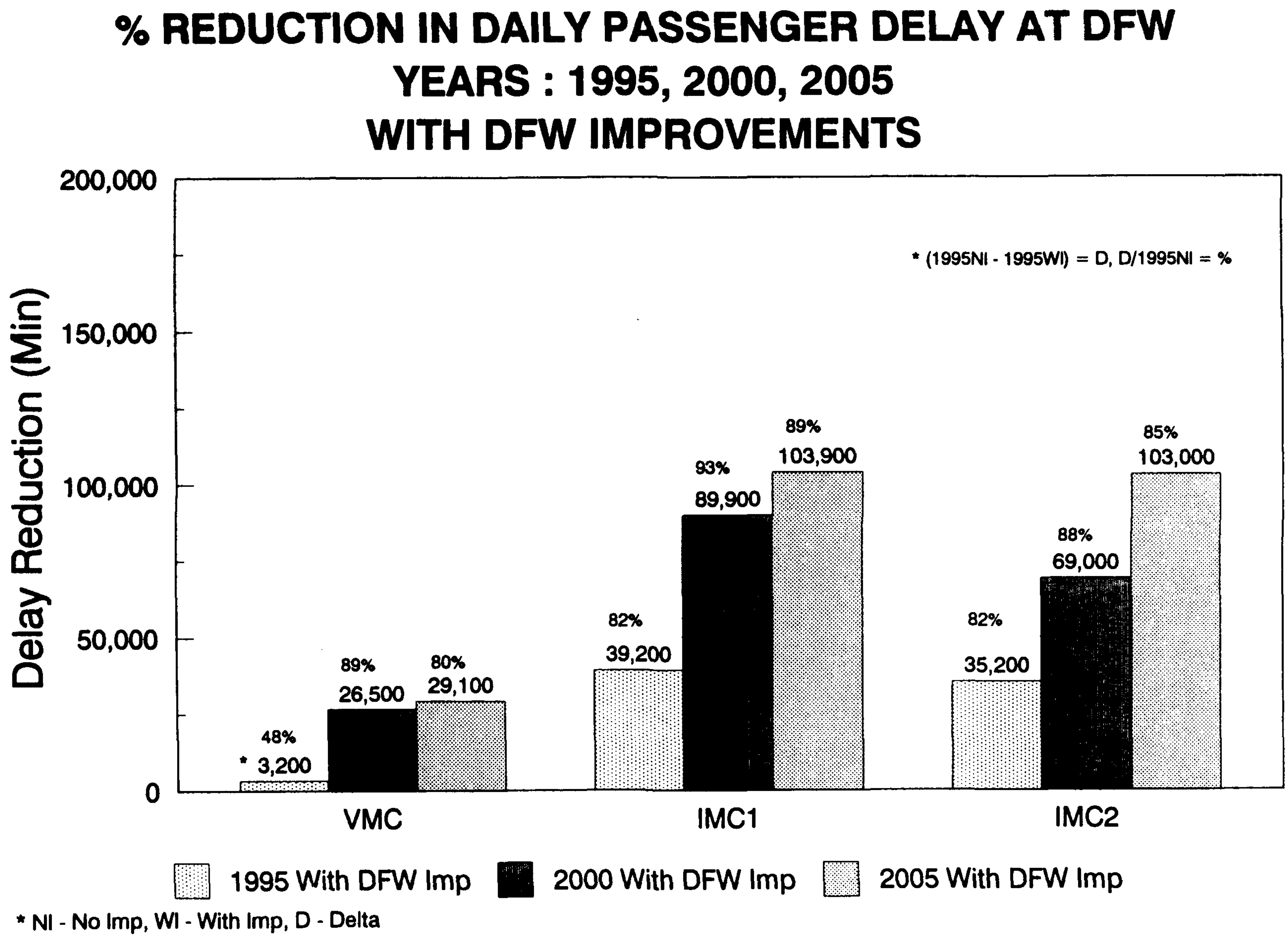



FIGURE 6. PERCENT REDUCTION IN PASSENGER DELAY AT DFW WITH PLAN

Plan, but the increase in delay is smaller with the plan. System-wide operational delay reduction for any given year is roughly equal to the operational delay reduction at DFW. This is not unusual since the airport expansion is at DFW. The results underscore the pivotal position of DFW as a hub in the NAS.

TABLE 11. AVERAGE PASSENGER DELAY AT DFW

Daily Average Minutes of Passenger Delay at DFW with and with No DFW Improvements

| SCEN | 1989 | 1995 | | 2000 | | 2005 | |
|---|---|---|---|---|---|---|---|
| | | NI | WI | NI | WI | NI | WI |
| VMC | 3.60 | 5.40 | 2.60 | 22.70 | 2.20 | 26.10 | 4.10 |
| IMC1 | 9.50 | 39.00 | 6.20 | 72.90 | 4.40 | 84.00 | 7.60 |
| IMC2 | 20.20 | 35.30 | 5.80 | 58.80 | 5.70 | 86.60 | 10.20 |

TABLE 12. PASSENGER DELAY SAVINGS AT DFW WITH PLAN

Annual Passenger Delay Savings at DFW (in millions) with DFW Improvements

| 1995 | 2000 | 2005 |
|---|---|---|
| $50 | $294 | $377 |

TABLE 13. OPERATIONAL DELAY SYSTEM-WIDE

Total Minutes of System-Wide Operational Delay

| SCEN | 1989 BL | 1995 No Imp | 1995 1 Rwy | 2000 No Imp | 2000 2 Rwys | 2005 No Imp | 2005 2 Rwys |
|---|---|---|---|---|---|---|---|
| VMC | 90,200 | 140,000 | 125,200 | 233,600 | 193,400 | 442,800 | 357,600 |
| IMC1 | 158,400 | 309,100 | 253,600 | 524,100 | 410,100 | 741,700 | 608,800 |
| IMC2 | 292,500 | 406,300 | 356,700 | 564,000 | 485,900 | 898,500 | 799,300 |

Without the Metroplex Plan, simulation results have shown that the operational delay in the NAS will increase. These estimates are shown in table 14.

TABLE 14. PERCENT INCREASE IN SYSTEM OPERATIONAL DELAY WITHOUT PLAN

Percent Increase in Daily System-Wide Operational Delay with No DFW Improvements

| SCEN | 1995 | 2000 | 2005 |
|---|---|---|---|
| VMC | 55% | 159% | 391% |
| IMC1 | 95% | 231% | 368% |
| IMC2 | 39% | 93% | 207% |

Figure 7 compares the reduction in operational delay system-wide for the three scenarios used in the study. As one would expect, the largest benefit of the plan is realized in the year 2000 under IMC1, the worst weather scenario (17 hours IMC at DFW), and with two new runways expected to be completed. The benefits continued to surface for the year 2005 as well; however, it diminished somewhat due to the increase in demand at DFW and no additional improvements modeled.

The daily system-wide operational delay are shown in table 15. Each value represents the average system-wide operational delay per aircraft with and without the Metroplex Plan.

System-wide operational delay savings due to the Metroplex Plan, were estimated for the years 1995, 2000, and 2005. They are shown in table 16.

Table 17 shows the estimated total system-wide passenger (effective arrival) delay in minutes for each of the scenario days and the time frames modeled. These values represent the baseline (1989) and future years simulated with and without the Metroplex Plan.

In contrast to system-wide operational delay, the reductions in passenger delay system-wide are greater than the reduction in passenger delay at DFW. Passenger delay reflects the ripple-effects of delay at a given airport. Since DFW may be one leg of an aircraft's itinerary, the on-time performance of flights passing through DFW would result in improved on-time performance of airports which serve DFW. Increased capacity at DFW would, thus, improve the on-time performance of successive legs of any flight itinerary including DFW.

## % REDUCTION DAILY SYSTEM WIDE OPERATIONAL DELAY YEARS : 1995, 2000, 2005 WITH DFW IMPROVEMENTS

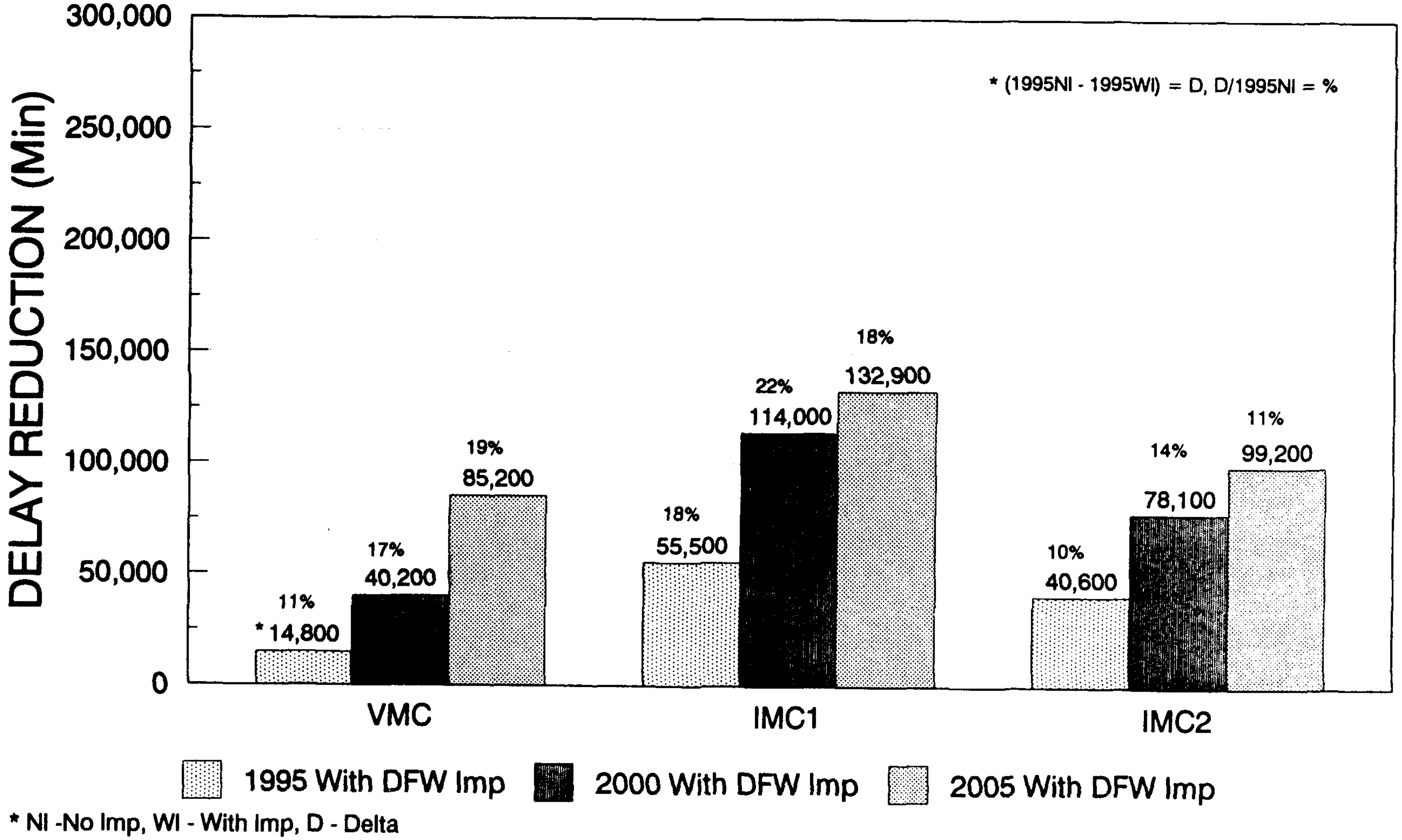



FIGURE 7. PERCENT REDUCTION IN SYSTEM OPERATIONAL DELAY WITH PLAN

TABLE 15. AVERAGE SYSTEM OPERATIONAL DELAY

Daily Average Minutes of System-Wide Operational Delay
with and with No DFW Improvements

| SCEN | 1989 | 1995 NI | 1995 WI | 2000 NI | 2000 WI | 2005 NI | 2005 WI |
|---|---|---|---|---|---|---|---|
| VMC | 1.40 | 1.90 | 1.80 | 3.10 | 2.40 | 5.20 | 4.20 |
| IMC1 | 2.60 | 4.40 | 3.50 | 6.70 | 5.30 | 9.00 | 7.30 |
| IMC2 | 4.80 | 5.80 | 5.20 | 7.30 | 6.30 | 10.90 | 9.60 |

TABLE 16. SYSTEM OPERATIONAL DELAY SAVINGS WITH PLAN

Annual System-Wide Operational Delay Savings (in millions)
with DFW Improvements

| 1995 | 2000 | 2005 |
|---|---|---|
| $162 | $217 | $313 |

TABLE 17. SYSTEM PASSENGER DELAY

Total Minutes of System-Wide Passenger Delay
(at Gate)

| SCEN | 1989 BL | 1995 No Imp | 1995 1 Rwy | 2000 No Imp | 2000 2 Rwys | 2005 No Imp | 2005 2 Rwys |
|---|---|---|---|---|---|---|---|
| VMC | 240,000 | 305,000 | 294,000 | 467,700 | 378,900 | 821,300 | 688,200 |
| IMC1 | 297,000 | 514,000 | 429,000 | 842,600 | 644,100 | 1,161,000 | 962,300 |
| IMC2 | 501,000 | 673,000 | 610,000 | 942,800 | 796,200 | 1,646,800 | 1427,770 |

The percent increase in daily system-wide passenger delay are shown in table 18. These simulation results are without the implementation of the Metroplex Plan.

TABLE 18. PERCENT INCREASE IN SYSTEM PASSENGER DELAY WITHOUT PLAN

Percent Increase in Daily System-Wide Passenger Delay with no DFW Improvements

| SCEN | 1995 | 2000 | 2005 |
|---|---|---|---|
| VMC | 27% | 95% | 242% |
| IMC1 | 73% | 184% | 291% |
| IMC2 | 34% | 88% | 229% |

The system-wide passenger delay was reduced in the simulation by the percentages illustrated in figure 8. In 1995, with only one new runway modeled, a substantial reduction in delay was observed. The Metroplex Plan has the greatest effect in 2000 with two new runways modeled under the worst weather scenario IMC1 for both DFW and system-wide. As the demand increases in 2005, the effect of the Metroplex Plan diminishes because there are no new improvements modeled with an increase in demand. This pattern is consistent for all scenarios and the time frame modeled for DFW and system-wide. These results are shown in figures 5, 6, 7 and 8.

The daily average minutes of system-wide passenger delay for the time frame modeled are shown in table 19. A reduction of the system-wide passenger delay was observed with the Metroplex Plan.

The estimated cost (in 1991 dollars) savings for system-wide passenger delay due to the Metroplex Plan is shown in table 20.

The analysis has shown that airports with the most DFW traffic will have greater benefits than the rest of the NAS. However, some airports show an increase in delay with the plan in place. This increase is shown at ORD, LAX, PHX, and SFO under IMC1 and IMC2 in 2000 and 2005. A reasonable explanation might suggest that the additional traffic that DFW accommodates would result in more departures. This would place a greater demand on arrivals for those airports which serve DFW. This increase coupled with no capacity enhancements would yield greater delays. The results for individual airports should be interpreted cautiously, inasmuch as they only pertain to the specific simulation scenario. Moreover,

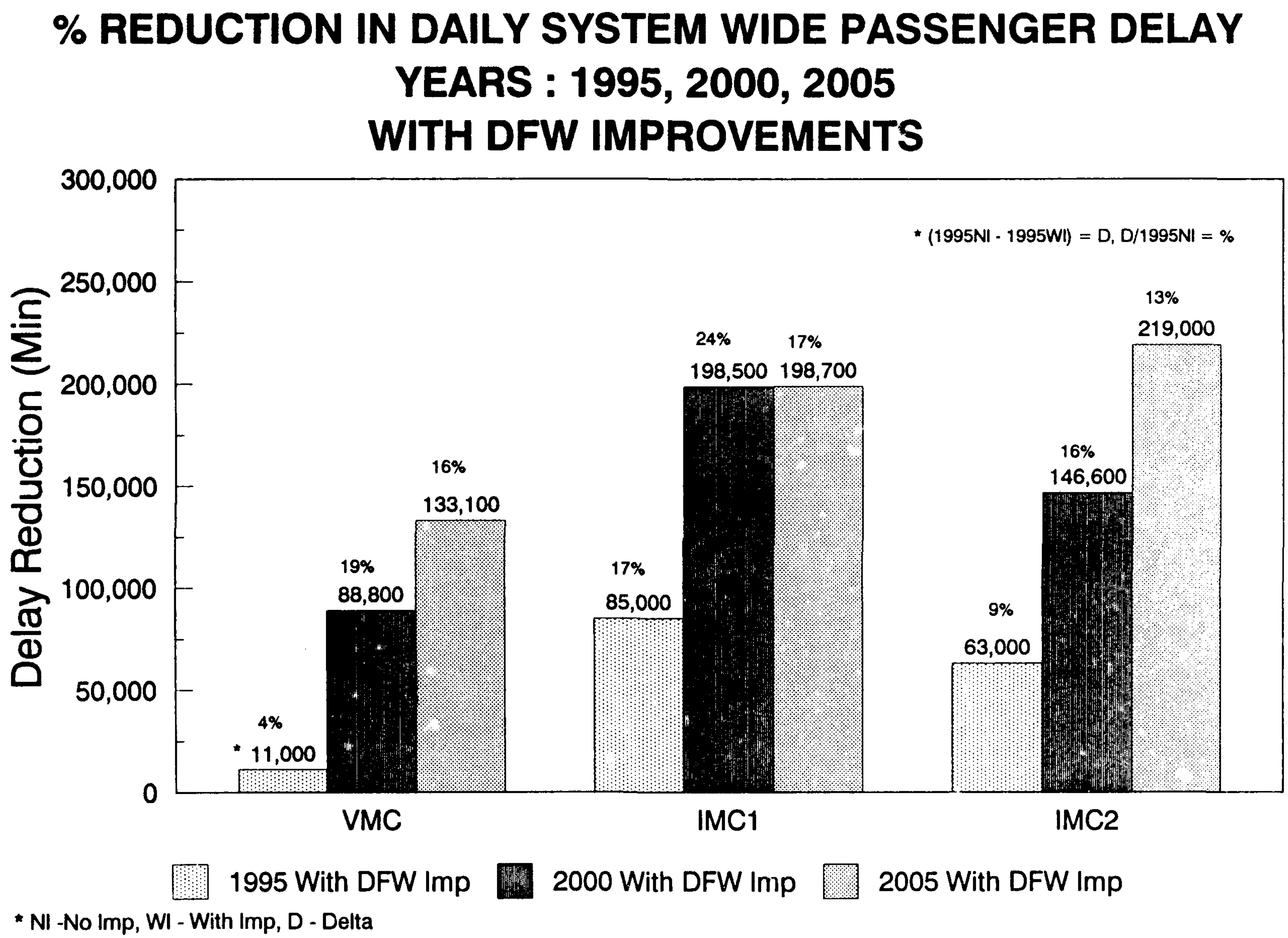



FIGURE 8. PERCENT REDUCTION IN SYSTEM PASSENGER DELAY WITH PLAN

in the real world, traffic flow management would probably mitigate these effects using methods not captured by the simulation.

TABLE 19. AVERAGE SYSTEM PASSENGER DELAY

Daily Average Minutes of System-Wide Passenger Delay with and with No DFW Improvements

| SCEN | 1989 | 1995 NI | 1995 WI | 2000 NI | 2000 WI | 2005 NI | 2005 WI |
|---|---|---|---|---|---|---|---|
| VMC | 3.90 | 4.30 | 4.10 | 6.20 | 4.80 | 9.80 | 8.20 |
| IMC1 | 4.90 | 7.30 | 6.00 | 10.90 | 8.30 | 14.10 | 11.60 |
| IMC2 | 8.40 | 9.70 | 8.70 | 12.30 | 10.40 | 20.10 | 17.40 |

TABLE 20. SYSTEM PASSENGER DELAY SAVINGS WITH PLAN

Annual Passenger Delay Savings System-Wide (in millions) with DFW Improvements

| 1995 | 2000 | 2005 |
|---|---|---|
| $233 | $444 | $705 |

The results in table 21 shows the percentages of daily savings in passenger delay at airports with most DFW traffic for the years 1995, 2000, and 2005 under IMC1 and IMC2.

## 4.3 AIRSPACE.

The study shows that the Metroplex Plan will have an effect on the DFW airspace. Table 22 shows the sum of operational delay at DFW for all arrival fixes for the modeled years.

The DFW arrival fix operational delay was reduced substantially in the simulation by the percentages shown in table 23, with the Metroplex Plan in place. The reduction is due to the design of the new route system.

The reduction in the departure fix operational delay are relatively minor compared to the arrival fix operational delay and were determined to be insignificant.

TABLE 21. PERCENT SAVINGS AT AIRPORTS THAT SHARE TRAFFIC WITH DFW

Percent in Daily Savings in Passenger Delay at Airports With Most DFW Traffic Under IMC1 and IMC2 With DFW Improvements

| ARPTS | 1995 IMC1 | 1995 IMC2 | 2000 IMC1 | 2000 IMC2 | 2005 IMC1 | 2005 IMC2 |
|---|---|---|---|---|---|---|
| ATL | 32% | 33% | 48% | 40% | 40% | 47% |
| ORD | 17% | -4% | 18% | -6% | 12% | -5% |
| DVX | 25% | 3% | 19% | 24% | 18% | 21% |
| IAH | 35% | 19% | 59% | 35% | 48% | 44% |
| LAX | 13% | 12% | 18% | 0% | -4% | -3% |
| DCA | 17% | 13% | 26% | 26% | 28% | 26% |
| PHX | 8% | 3% | 11% | 6% | -9% | 6% |
| SAT | 31% | 26% | 36% | 8% | 26% | 18% |
| SFO | 18% | 0% | 27% | -3% | -5% | 1% |

TABLE 22. DFW ARRIVAL FIX OPERATIONAL DELAY

DFW Arrival Fix Delay With and Without Plan

| SCEN | 1989 BL | 1995 No Imp | 1995 1 Rwy | 2000 No Imp | 2000 2 Rwys | 2005 No Imp | 2005 2 Rwys |
|---|---|---|---|---|---|---|---|
| VMC | 930 | 1,126 | 156 | 1,087 | 257 | 1,090 | 368 |
| IMC1 | 616 | 765 | 150 | 994 | 222 | 986 | 256 |
| IMC2 | 511 | 800 | 152 | 842 | 202 | 831 | 246 |

## 5. CONCLUSIONS.

The results indicate that the increased capacity provided by the Metroplex Plan (particularly the addition of new runways), result in a significant reduction in delay at DFW and system-wide. The reduction in delay with and without the plan was evident despite the additional demand placed on DFW for future years. The analysis also showed that key airports that share traffic with DFW will benefit from the plan.

A comparison of the reductions in daily passenger delay at DFW and system-wide with the Metroplex Plan in place is given in table 24.

The annual savings in passenger cost at DFW and system-wide in the year 2005 were estimated at $377 and $705 million, respectively, with cumulative savings for the years 1995 through 2005) of $2.751 and $5.034 billion (in 1991 dollars).

TABLE 23. REDUCTION AT DFW ARRIVAL FIX OPERATIONAL DELAY

Percent Reduction at DFW Arrival Fix Operational Delay With the Plan

| SCEN | 1995 | 2000 | 2005 |
|---|---|---|---|
| VMC | 86% | 76% | 66% |
| IMC1 | 80% | 78% | 74% |
| IMC2 | 81% | 76% | 70% |

TABLE 24. PERCENT REDUCTION IN PASSENGER DELAY AT DFW AND NAS WITH PLAN

Percent Reduction in Daily Passenger Delay With DFW Improvements

| | 1995 | | 2000 | | 2005 | |
|---|---|---|---|---|---|---|
| SCEN | DFW | NAS | DFW | NAS | DFW | NAS |
| VMC | 48% | 4% | 89% | 19% | 80% | 16% |
| IMC1 | 82% | 17% | 93% | 24% | 89% | 17% |
| IMC2 | 82% | 9% | 88% | 16% | 85% | 13% |

The work on this study has generated reasonable and conservative estimates of the cost of delay under a variety of possible conditions. Table 25 shows the savings estimates for a 10-year period (1995 - 2005) at DFW broken down by operational cost and passenger cost.

TABLE 25. DFW COST ESTIMATE SAVINGS FOR A 10-YEAR PERIOD

Delay Savings Estimates for 10-Year Period
DFW 10-Year Delay Savings (1991 dollars)

| Year | Operation Cost | Passenger Cost | Total Cost |
|---|---|---|---|
| 1995 | $98,000,000 | $50,000,000 | $148,000,000 |
| 1996 | 111,400,000 | 98,800,000 | 210,200,000 |
| 1997 | 124,800,000 | 147,600,000 | 272,400,000 |
| 1998 | 138,200,000 | 196,400,000 | 334,600,000 |
| 1999 | 151,600,000 | 245,200,000 | 396,800,000 |
| 2000 | 165,000,000 | 294,000,000 | 459,000,000 |
| 2001 | 172,400,000 | 310,600,000 | 483,000,000 |
| 2002 | 179,800,000 | 327,200,000 | 507,000,000 |
| 2003 | 187,200,000 | 343,800,000 | 531,000,000 |
| 2004 | 194,600,000 | 360,400,000 | 555,000,000 |
| 2005 | 202,000,000 | 377,000,000 | 579,000,000 |
| Totals | $1,725,000,000 | $2,751,000,000 | $4,476,000,000 |

Table 26 shows the estimates of savings for a 10-year period (1995 - 2005) system-wide broken down by operational cost, passenger cost, and the total cost. Linear interpolation was used to estimate the savings for the years that were not modeled.

Table 27 shows the potential savings that were estimated from a previous SIMMOD study for a 10-year period (1995 - 2005) at DFW. The SIMMOD study focused on operational delay costs only and did not consider passenger delay costs. SIMMOD also used different TAF data indicating a 30 percent increase in traffic. SIMMOD was designed to simulate the details of an airport where NASPAC

considers the entire NAS, which encompasses 58 of the busiest, airports in the country. The SIMMOD study used 2 VFR days and 1 IMC day, while this study used 1 VMC day, 1 severe IMC (17 hours) day, and one less severe IMC (6 hours) day. This NASPAC study addresses the impact of the Metroplex Plan locally and system-wide. Linear interpolation was used as well to estimate the savings for the years that were not modeled.

TABLE 26. SYSTEM COST ESTIMATE SAVINGS FOR 10-YEAR PERIOD

Delay Savings Estimates for 10-Year Period
System-Wide 10-year Delay Savings (1991 dollars)

| Year | Operation Cost | Passenger Cost | Total Cost |
|---|---|---|---|
| 1995 | $162,000,000 | $233,000,000 | $395,000,000 |
| 1996 | 173,000,000 | 275,200,000 | 448,200,000 |
| 1997 | 184,000,000 | 317,400,000 | 501,400,000 |
| 1998 | 195,000,000 | 359,600,000 | 554,600,000 |
| 1999 | 206,000,000 | 401,800,000 | 607,800,000 |
| 2000 | 217,000,000 | 444,000,000 | 661,000,000 |
| 2001 | 236,200,000 | 496,200,000 | 732,400,000 |
| 2002 | 255,400,000 | 548,400,000 | 803,800,000 |
| 2003 | 274,600,000 | 600,600,000 | 875,200,000 |
| 2004 | 293,800,000 | 652,800,000 | 946,600,000 |
| 2005 | 313,000,000 | 705,000,000 | 1,018,000,000 |
| Totals | $2,510,000,000 | $5,034,000,000 | $7,544,000,000 |

TABLE 27. DFW COST ESTIMATE SAVINGS USING SIMMOD

Delay Savings Estimates for 10-Year Period
Delay Saving Estimate from Previous SIMMOD Study

| Year | Operation Cost | Passenger Cost | Total Cost |
|---|---|---|---|
| 1995 | $72,000,000 | Not Included | $72,000,000 |
| 1996 | 81,800,000 | = = | 81,800,000 |
| 1997 | 91,600,000 | = = | 91,600,000 |
| 1998 | 101,400,000 | = = | 101,400,000 |
| 1999 | 111,200,000 | = = | 111,200,000 |
| 2000 | 121,000,000 | = = | 121,000,000 |
| 2001 | 191,500,000 | = = | 191,500,000 |
| 2002 | 262,000,000 | = = | 262,000,000 |
| 2003 | 332,500,000 | = = | 332,500,000 |
| 2004 | 403,000,000 | = = | 403,000,000 |
| 2005 | 473,500,000 | = = | 473,500,000 |
| Totals | $2,242,000,000 | = = | $2,242,000,000 |

## 6. REFERENCES.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4. White, Michael J., Effects of a Second New Runway at DFW, W44-L106 1763F, MITRE, Mclean, VA, September 17, 1990.

5. Baart, Douglas, Joseph M. Richie, and Kimberly A. May, Cost of Delay Module, DOT/FAA/CT-TN91/52, FAA Technical Center, November 1991.

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7. Uhlenhaker, Ron, Allan N. Crocker, and Quentin G. Ogilive, D/FW Metroplex Plan Air Traffic System Plan, Dallas/Fort Worth Airport Board, D/FW Metroplex Air Traffic System Plan Program Office, July 2, 1992.

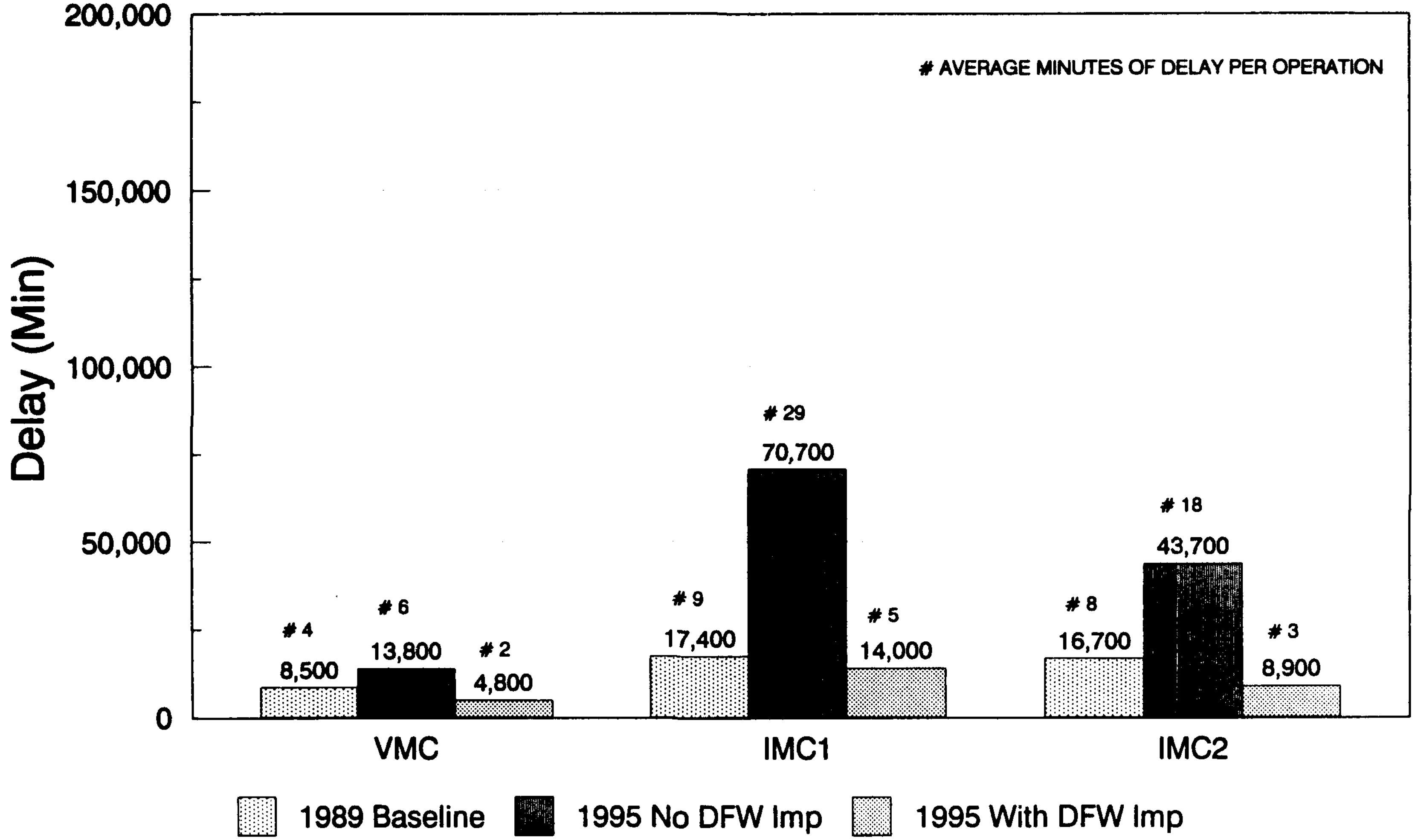
8. Weiss, William E., Estimating Airports Capacities for Use in the NASPAC Simulation Model, MITRE, Mclean, VA, June 1990.

## APPENDIX A

## RESULTS IN GRAPHICAL FORM

This appendix shows the results presented in section 4 graphically. The plotted values are exact, and may not precisely match the rounded values presented throughout this report.

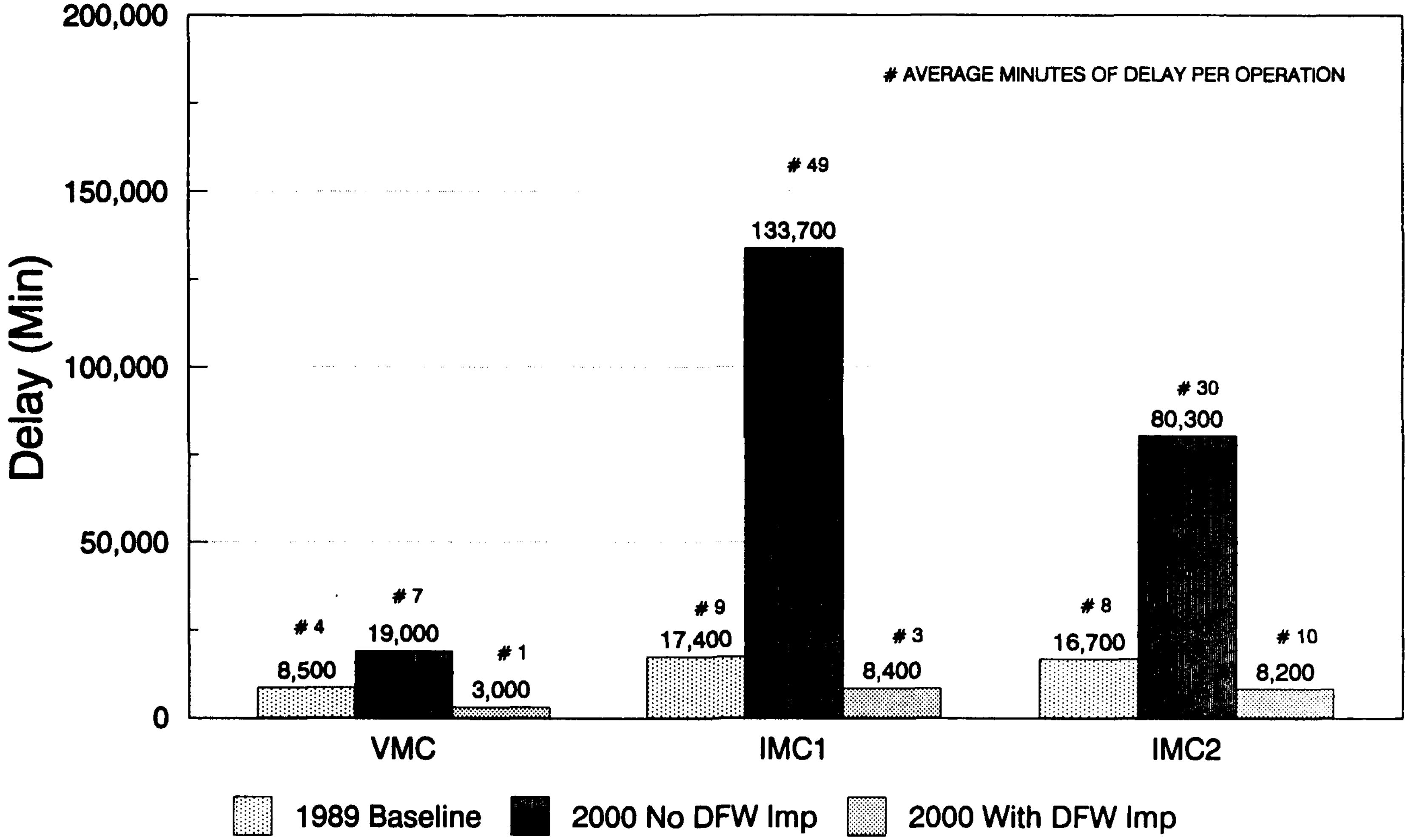
# DAILY OPERATIONAL DELAY At DFW
# * YEARS : 1989 BL, 1995 NI, 1995 WI




* BL - Baseline, NI - No Imp, WI - With Imp
OD - Operational Delay

OD = (Dept Del(Wheels_off) + Arr Del(Wheels_on))

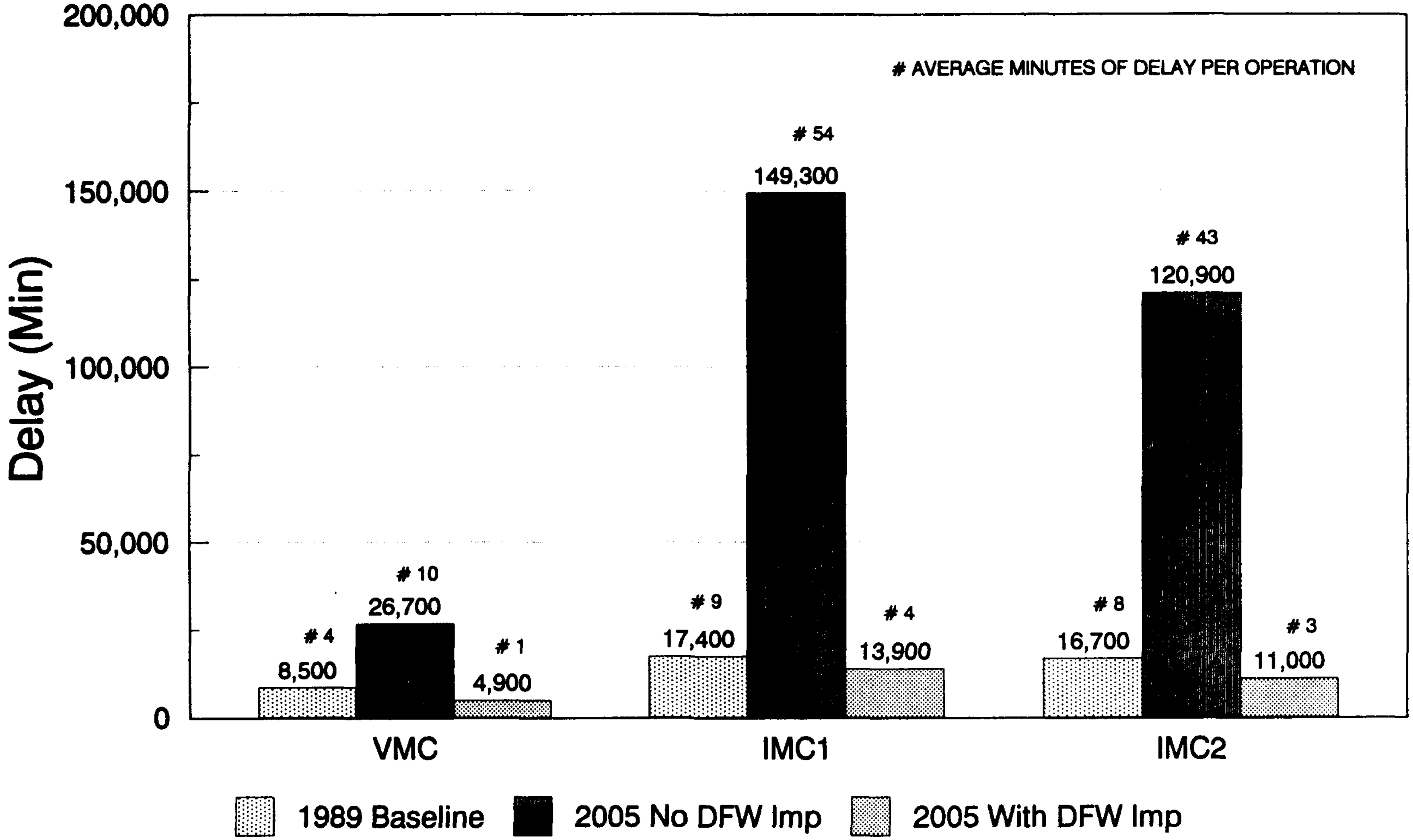
# DAILY OPERATIONAL DELAY AT DFW
# * YEARS : 1989 BL, 2000 NI, 2000 WI




* BL - Baseline, NI - No Imp, WI - With Imp
OD - Operational Delay

OD = (Dept Del(Wheels_off) + Arr Del(Wheels_on))

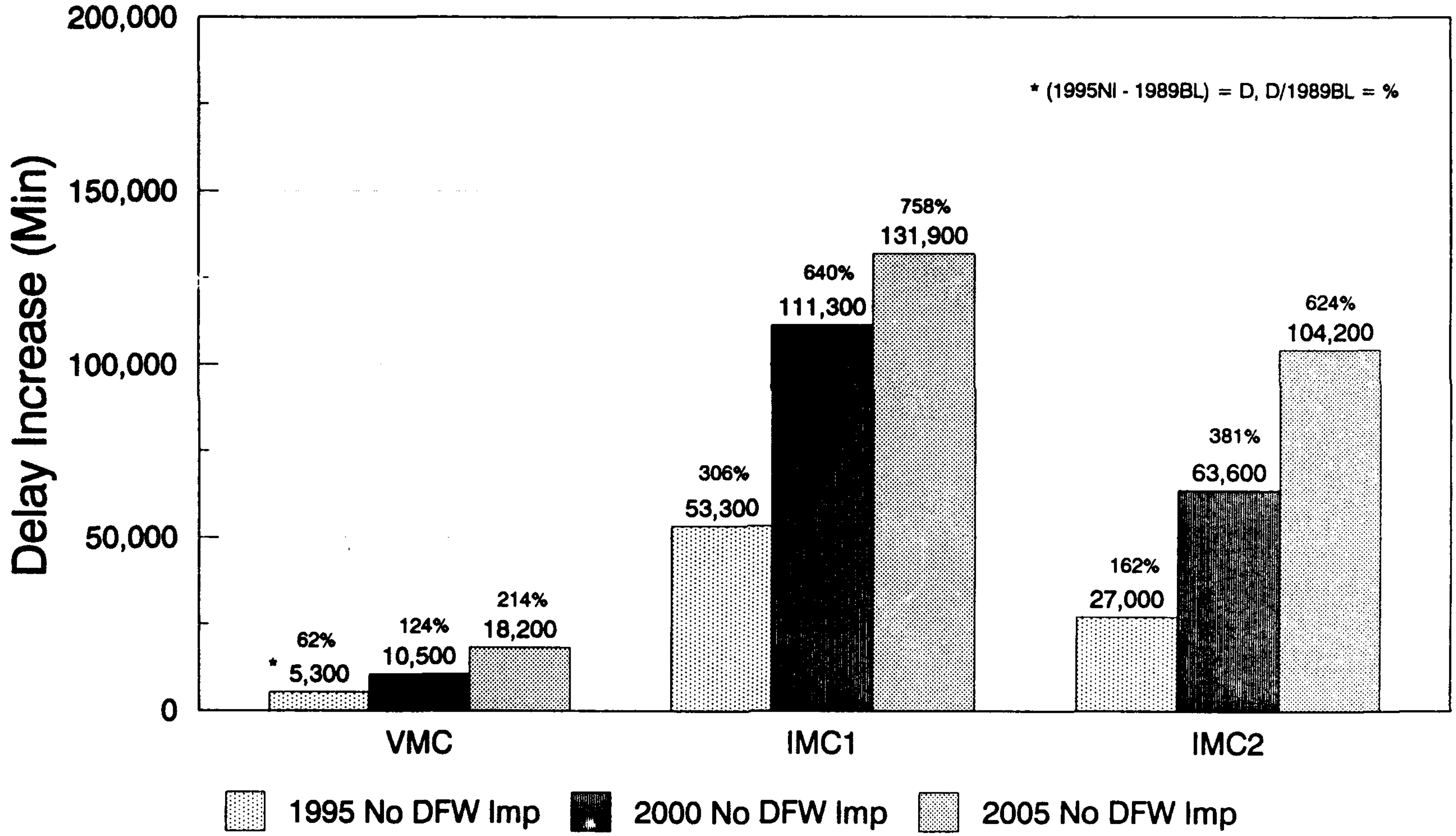
# DAILY OPERATIONAL DELAY AT DFW
## * YEARS : 1989 BL, 2005 NI, 2005 WI




* BL - Baseline, NI - No Imp, WI - With Imp
OD - Operational Delay

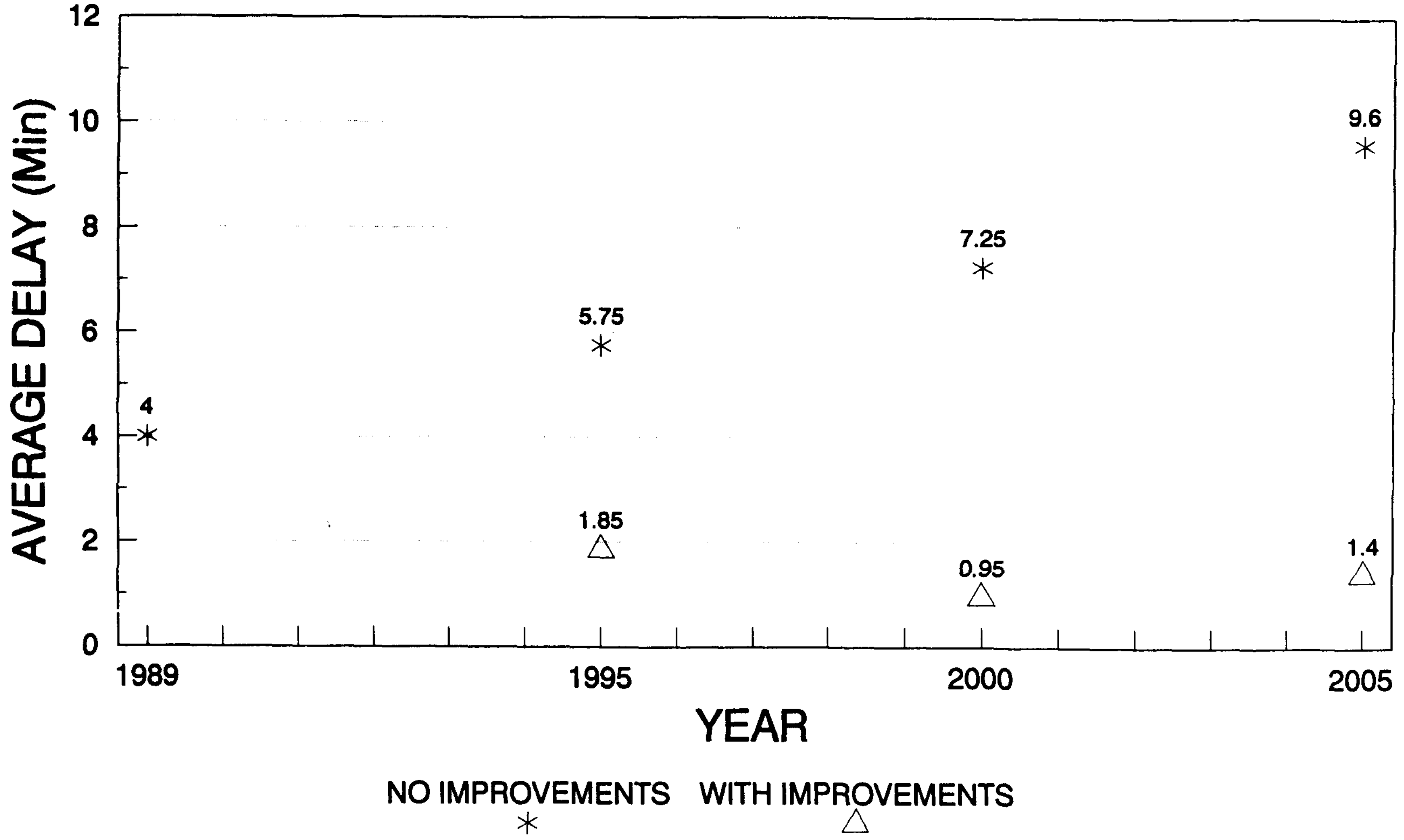
OD = (Dept Del(Wheels_off) + Arr Del(Wheels_on))

% INCREASE IN DAILY OPERATIONAL DELAY AT DFW
YEARS :1995, 2000, 2005
WITH NO DFW IMPROVEMENTS

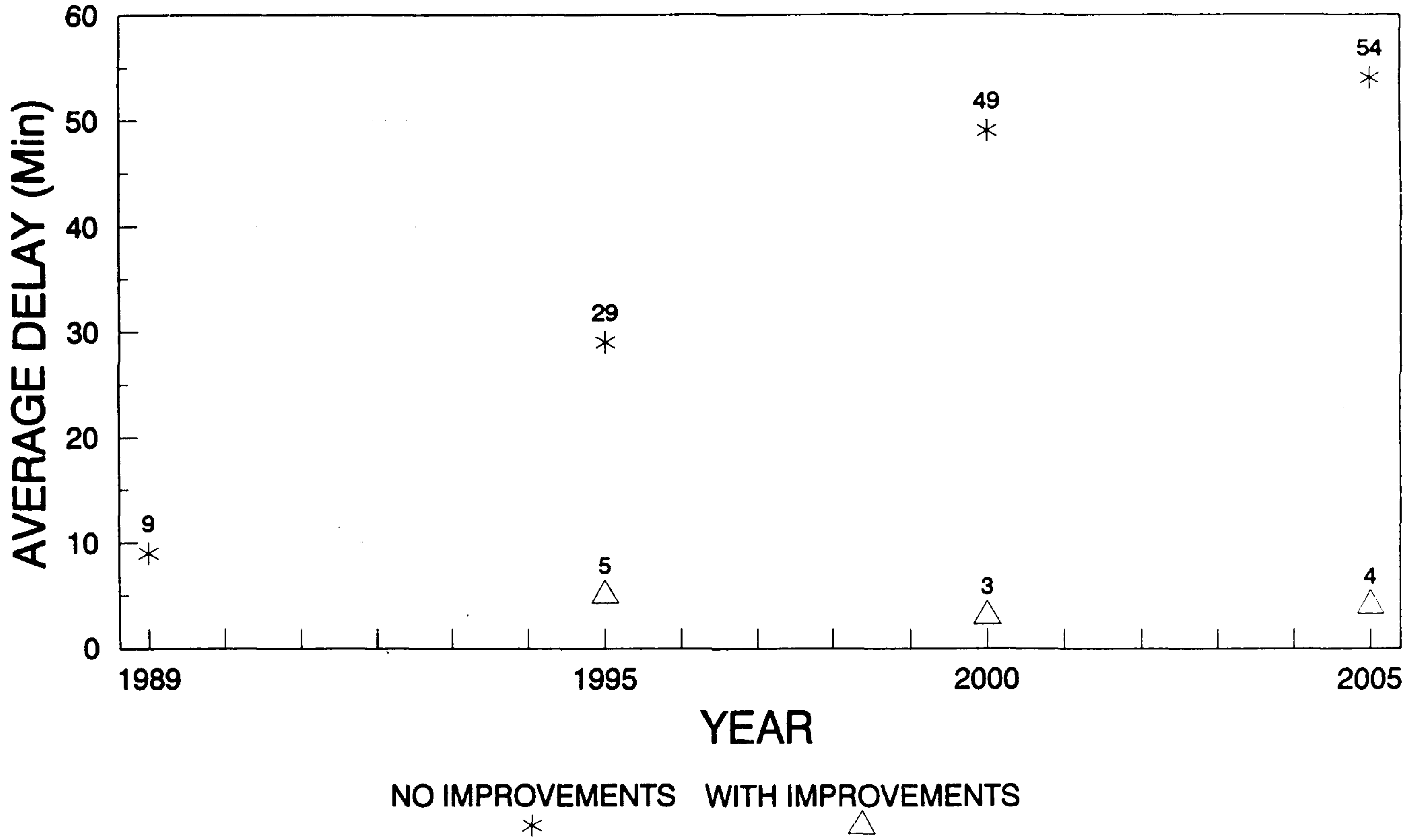



* BL - Baseline, NI - No Imp, D - Delta

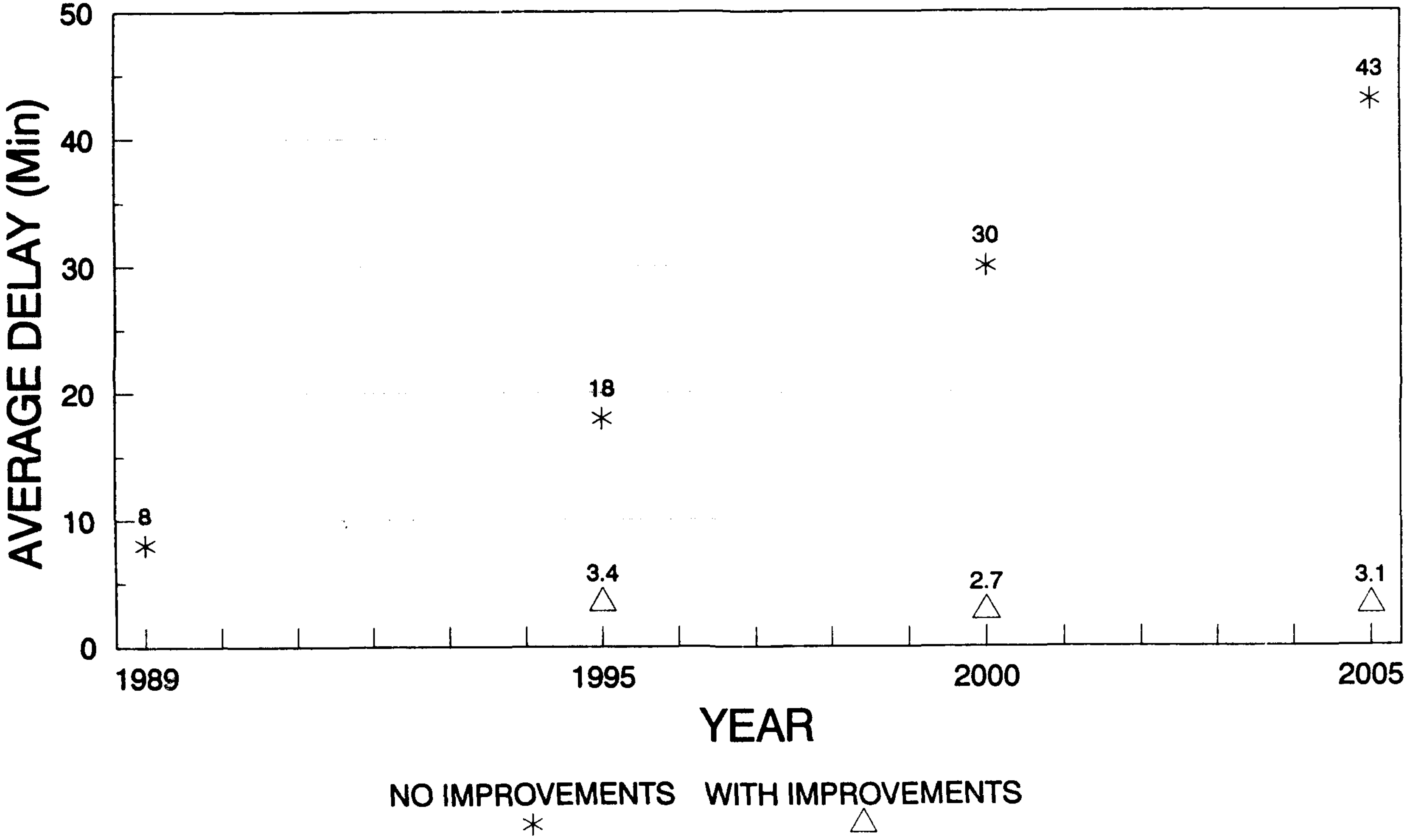
## DAILY AVERAGE MIN. OF OPERATIONAL DELAY AT DFW
## YEARS : 1989, 1995, 2000, 2005, (March 22, 89)
## VMC (Wx Sys. wide & DFW, near or at max. cap.)



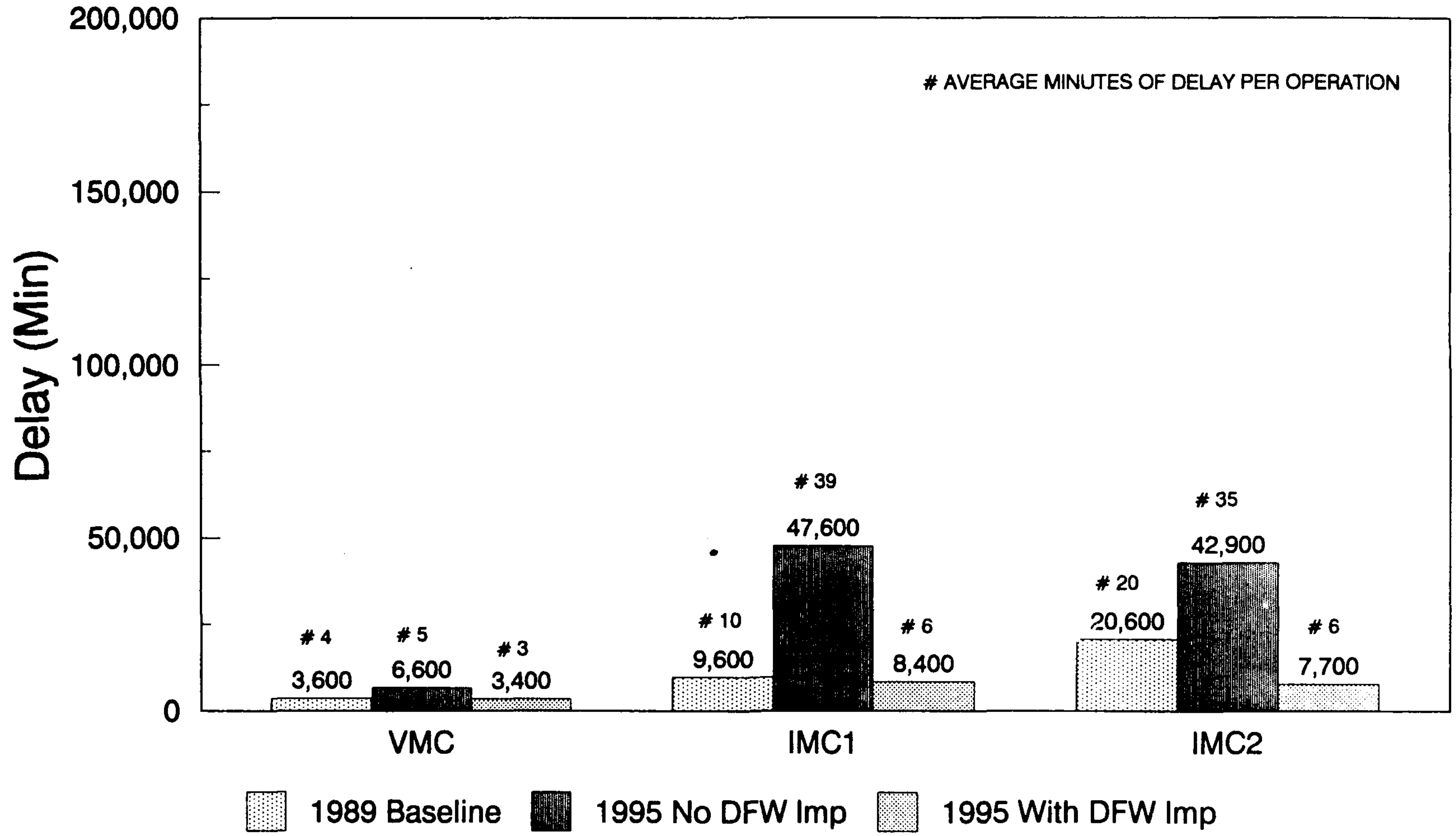
**DAILY AVERAGE MIN. OF OPERATIONAL DELAY AT DFW**
**YEARS : 1989, 1995, 2000, 2005**
**IMC1 (17 Hrs of IMC Wx at DFW, February 14, 89)**



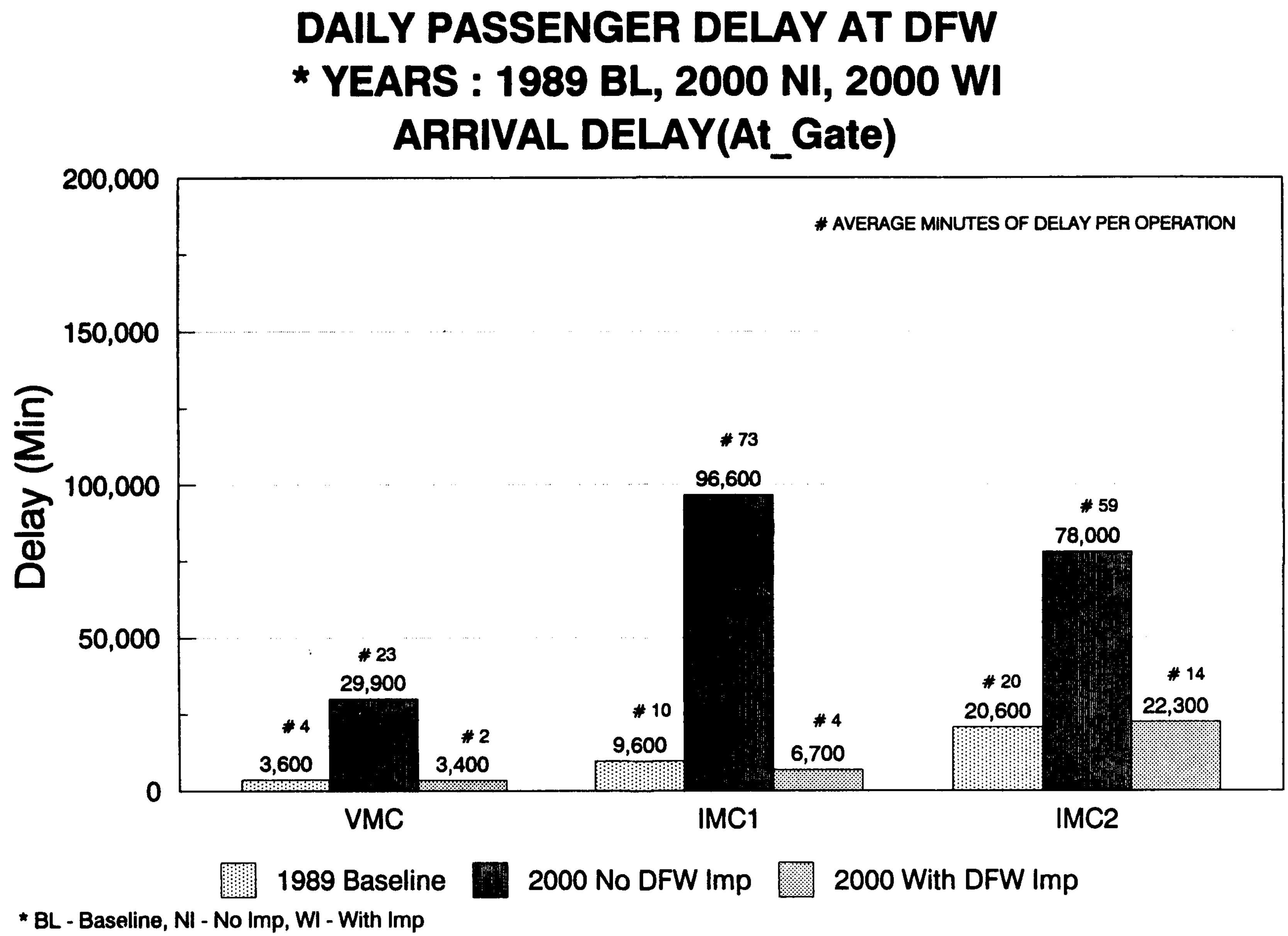
DAILY AVERAGE MIN. OF OPERATIONAL DELAY AT DFW
YEARS : 1989, 1995, 2000, 2005
IMC2 ( 6 Hrs of IMC Wx at DFW, March 2, 89)



# DAILY PASSENGER DELAY AT DFW
## * YEARS : 1989 BL, 1995 NI, 1995 WI
## ARRIVAL DELAY(At_Gate)



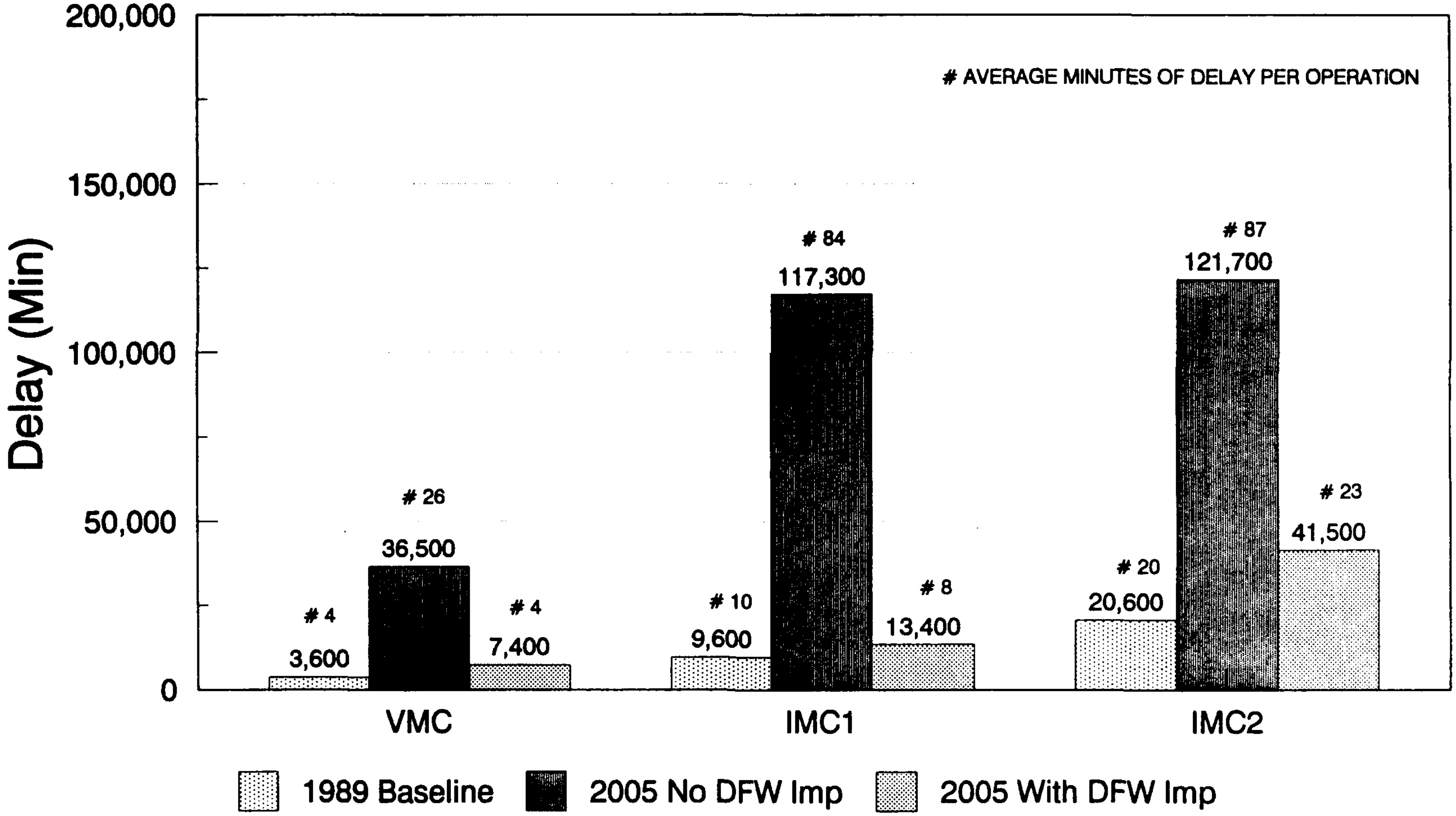

* BL - Baseline, NI - No Imp, WI - With Imp


DAILY PASSENGER DELAY AT DFW
* YEARS : 1989 BL, 2000 NI, 2000 WI
ARRIVAL DELAY(At_Gate)
# AVERAGE MINUTES OF DELAY PER OPERATION
Delay (Min)
200,000
150,000
100,000
50,000
0
# 4
3,600
# 23
29,900
# 2
3,400
# 10
9,600
# 73
96,600
# 4
6,700
# 20
20,600
# 59
78,000
# 14
22,300
VMC
IMC1
IMC2
1989 Baseline
2000 No DFW Imp
2000 With DFW Imp
* BL - Baseline, NI - No Imp, WI - With Imp

# DAILY PASSENGER DELAY AT DFW

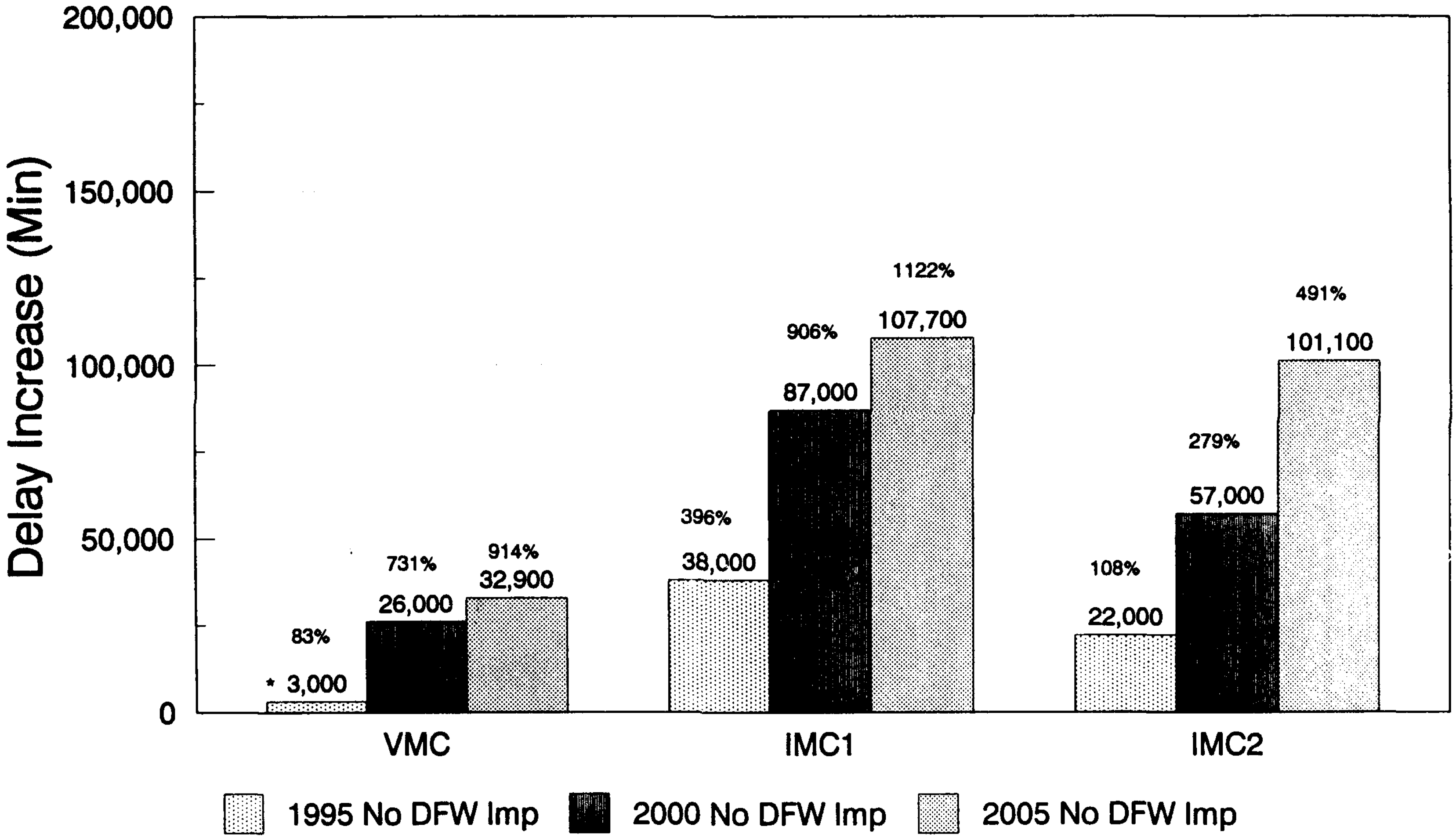
## * YEARS : 1989 BL, 2005 NI, 2005 WI

## ARRIVAL DELAY(At_Gate)




* BL - Baseline, NI - No Imp, WI - With Imp

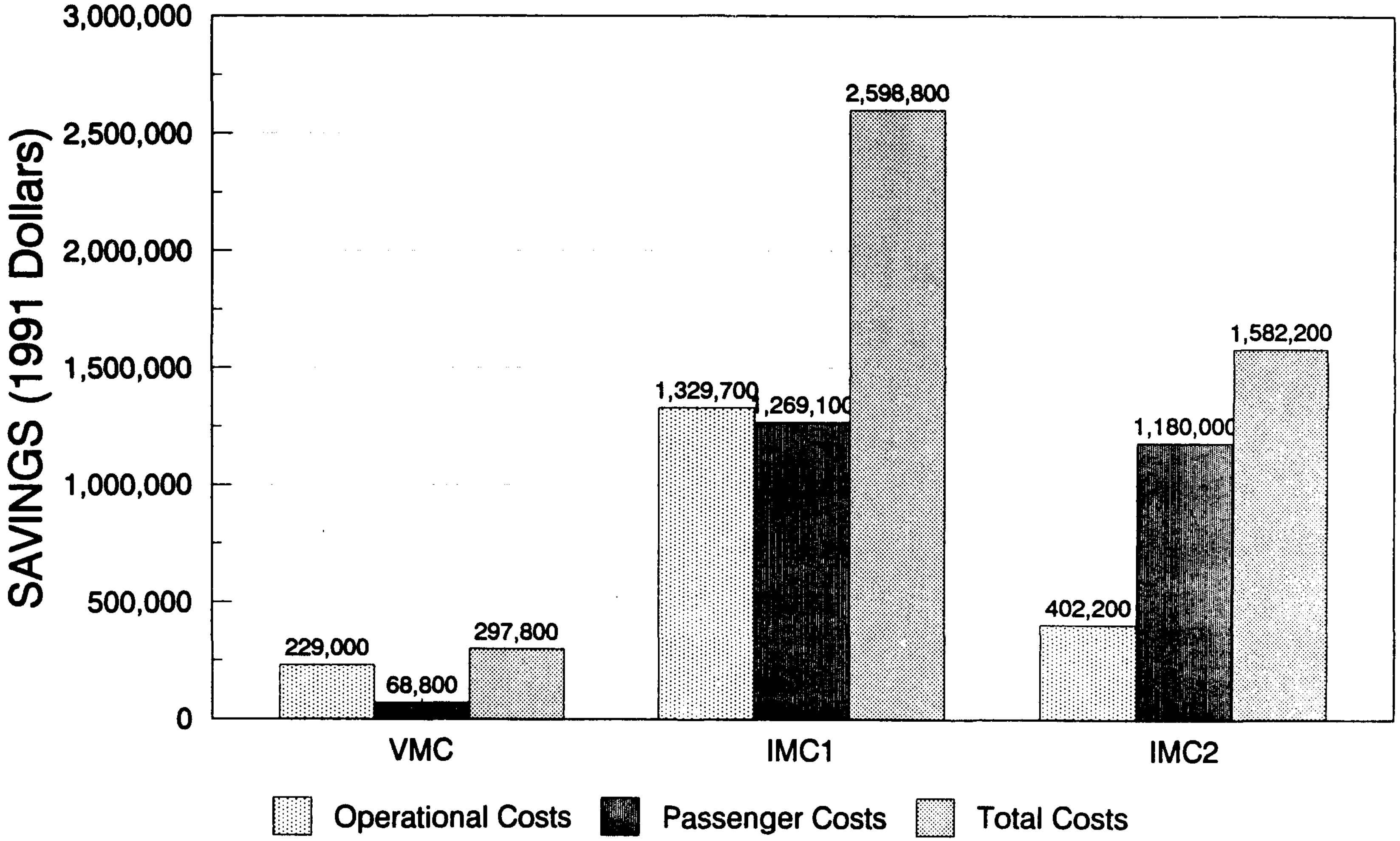
# % INCREASE IN DAILY PASSENGER DELAY AT DFW
# YEARS : 1995, 2000, 2005
# WITH NO DFW IMPROVEMENTS



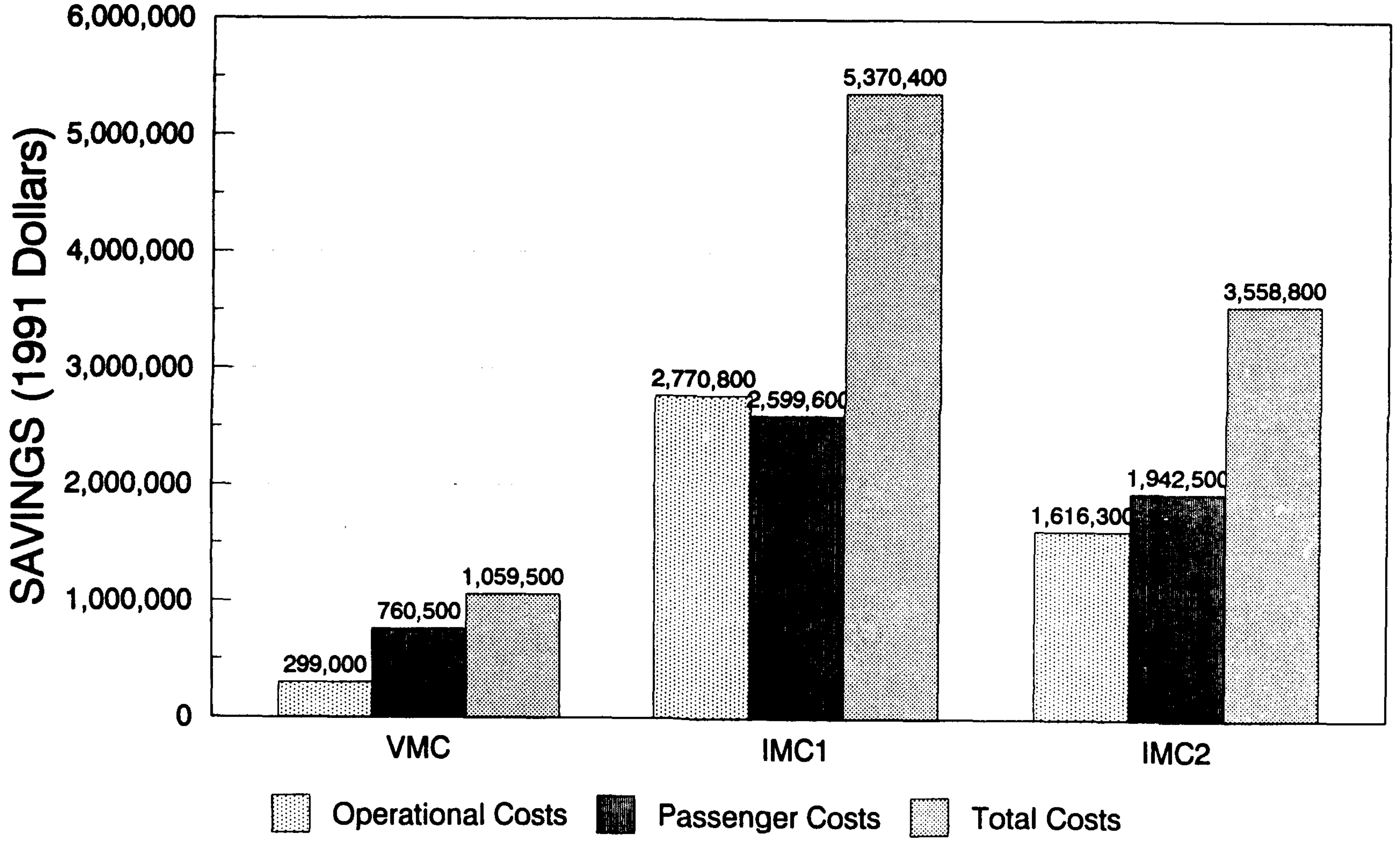

* BL - Baseline, NI - No Imp, D - Delta

* (1995NI - 1989BL) = D, D/1989BL = %

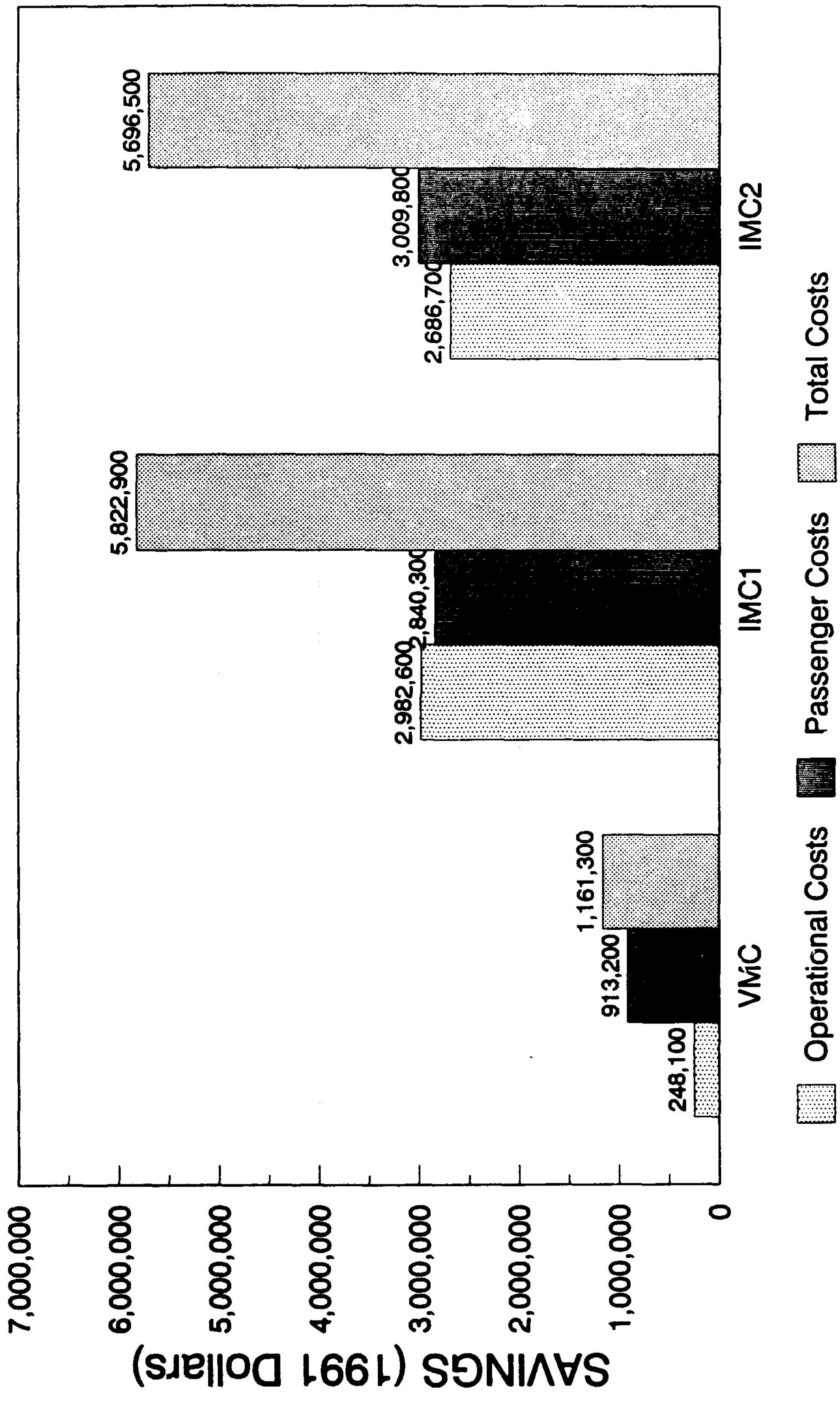
# DAILY DELAY SAVINGS AT DFW
# YEAR 1995
# WITH DFW IMPROVEMENTS



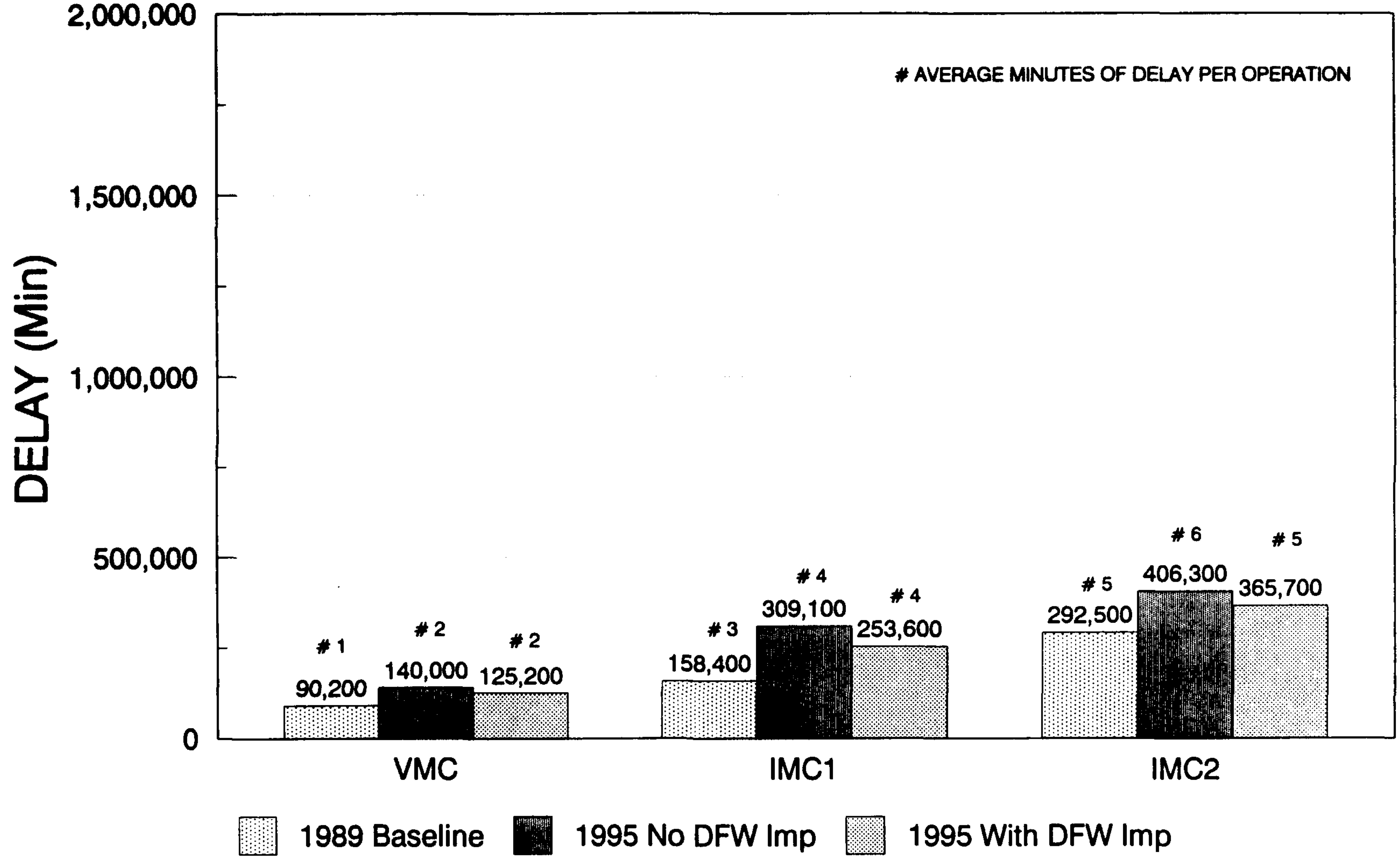
# DAILY DELAY SAVINGS AT DFW
# YEAR 2000
# WITH DFW IMPROVEMENTS



# DAILY DELAY SAVINGS AT DFW
# YEAR 2005
# WITH DFW IMPROVEMENTS

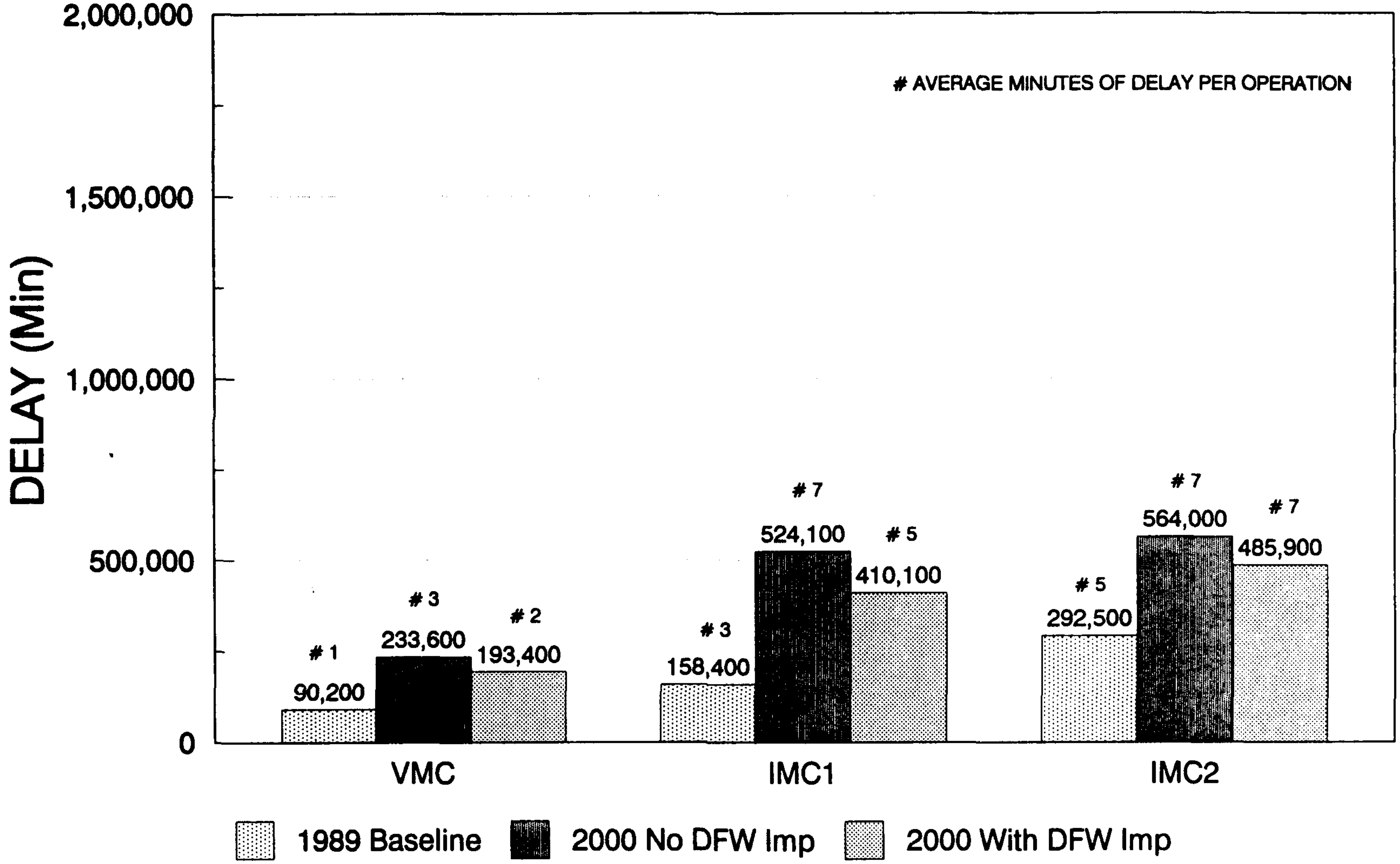


## DAILY SYSTEM WIDE OPERATIONAL DELAY
## * YEARS : 1989 BL, 1995 NI, 1995 WI




* BL - baseline, NI - No Imp, WI - With Imp

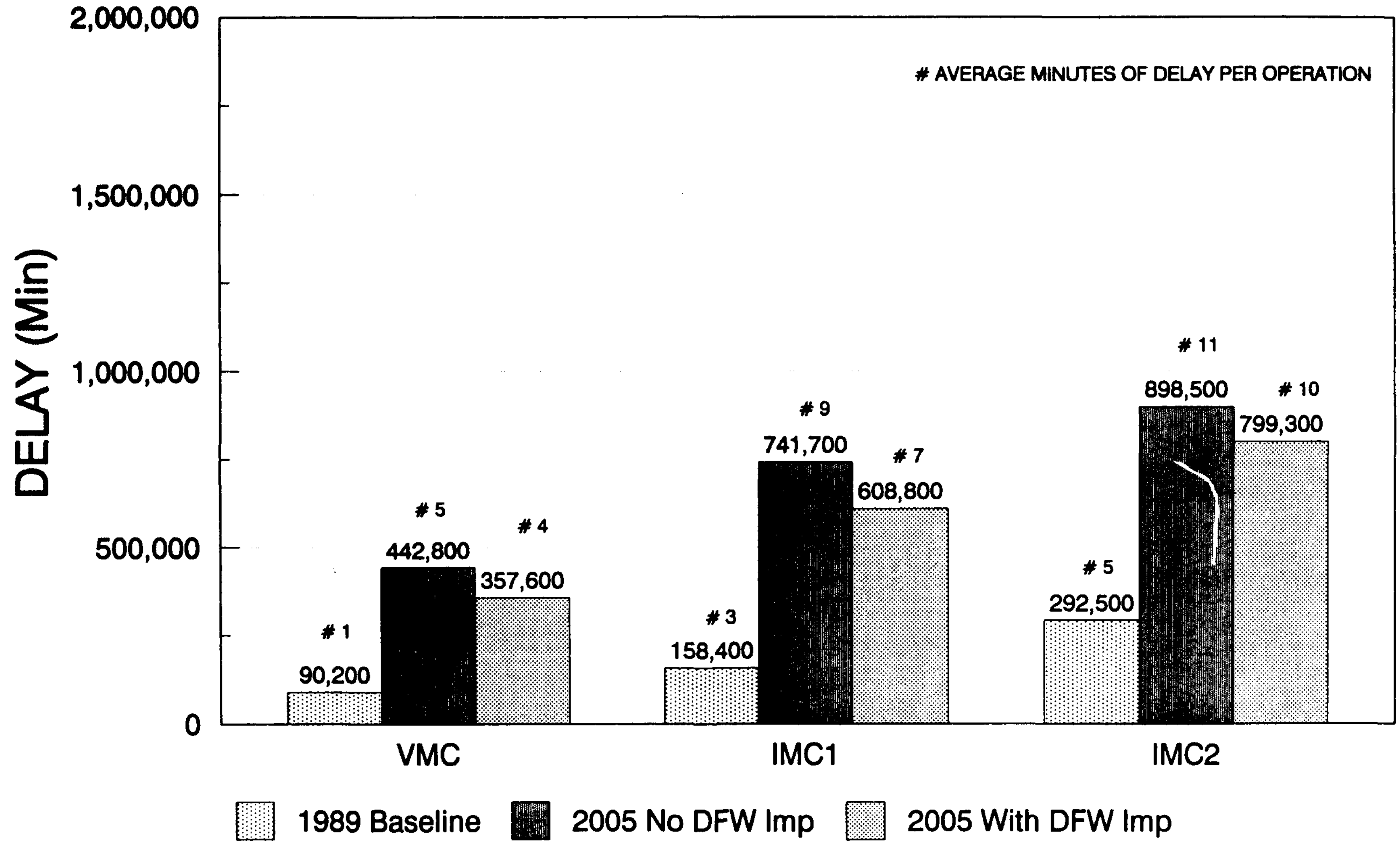
## DAILY SYSTEM WIDE OPERATIONAL DELAY
## * YEARS : 1989 BL, 2000 NI, 2000 WI




* BL - baseline, NI - No Imp, WI - With Imp

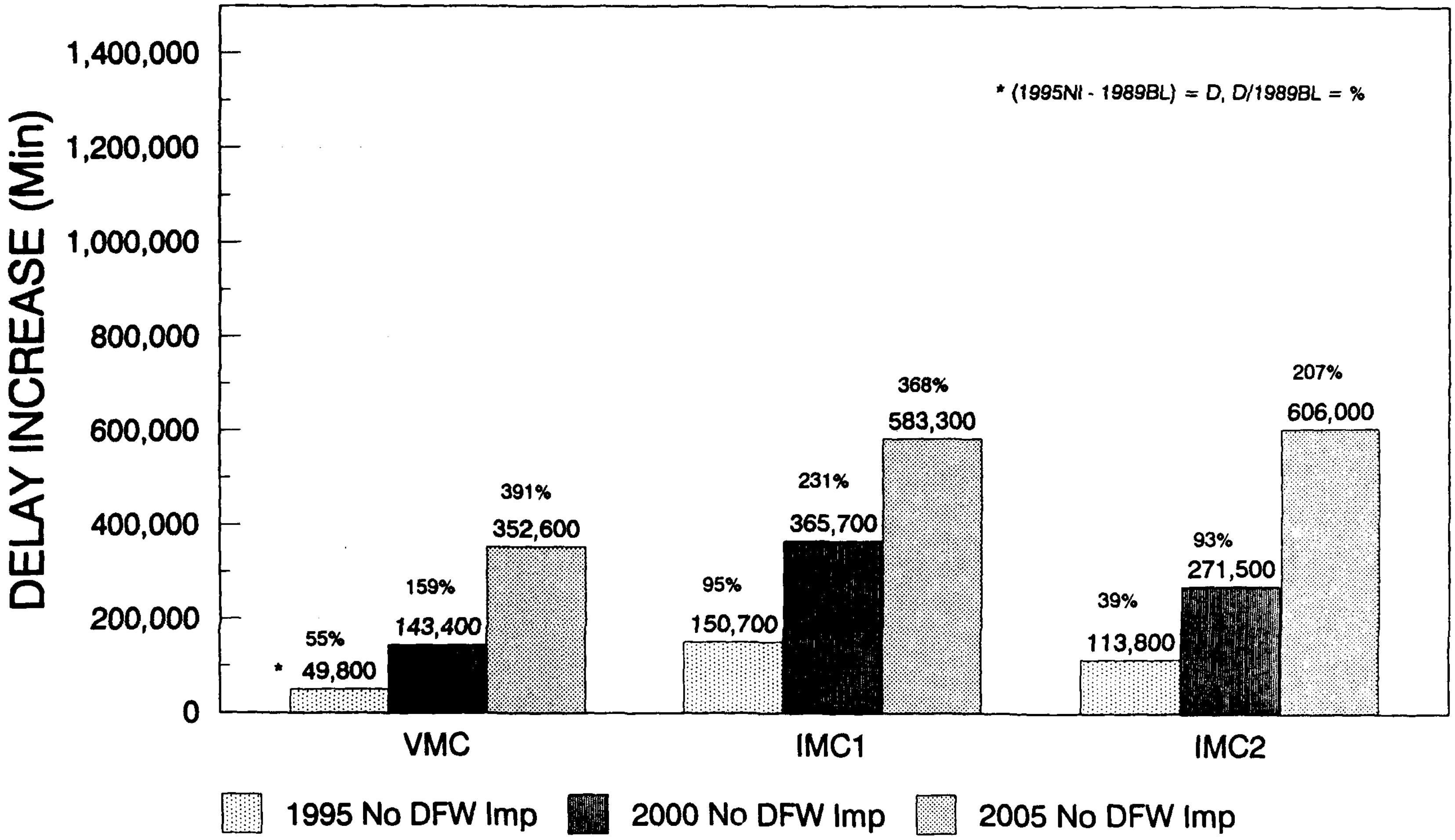
# DAILY SYSTEM WIDE OPERATIONAL DELAY

## * YEARS : 1989 BL, 2005 NI, 2005 WI



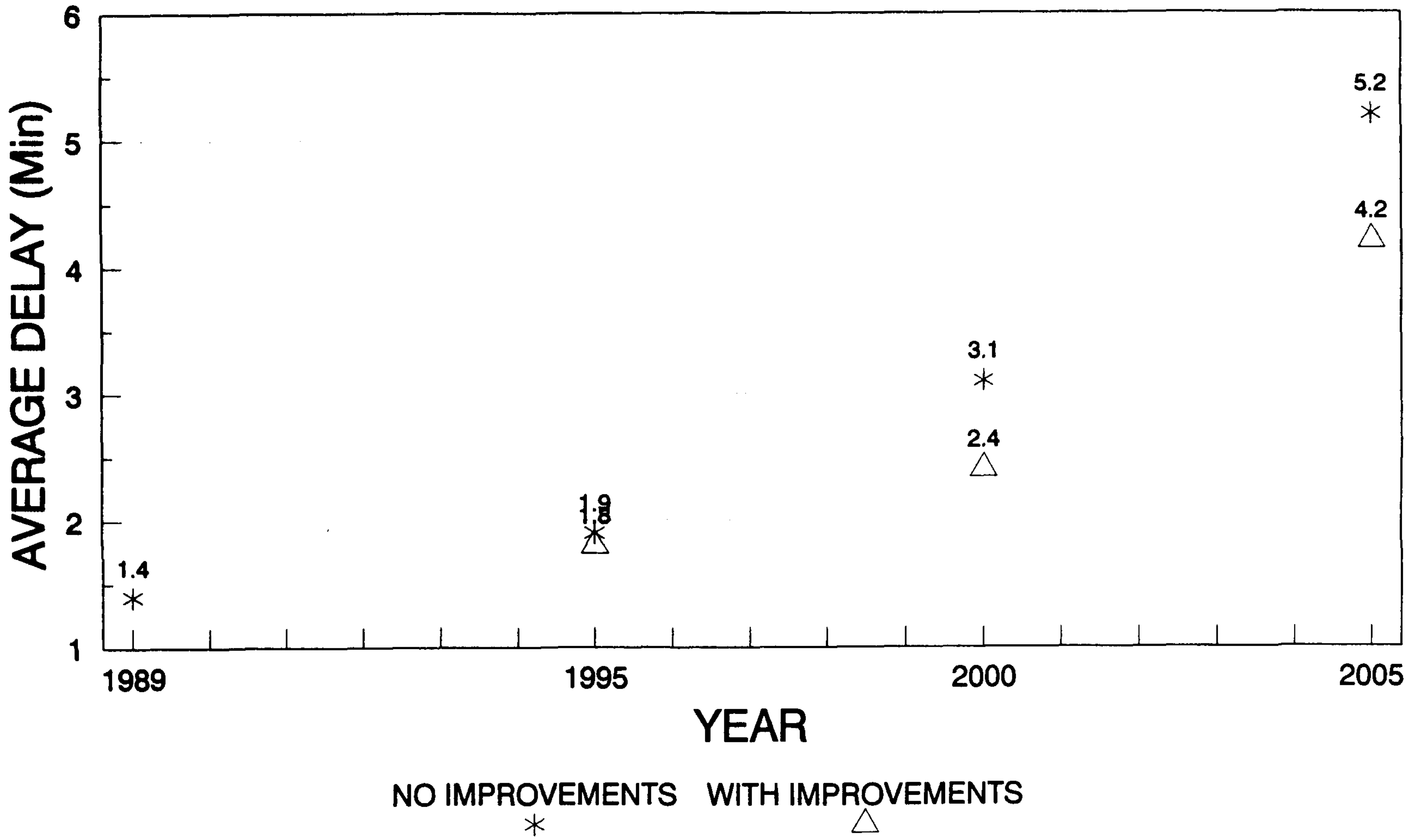

* BL - baseline, NI - No Imp, WI - With Imp

# % INCREASE DAILY SYSTEM WIDE OPERATIONAL DELAY YEARS : 1995, 2000, 2005 WITH NO DFW IMPROVEMENTS

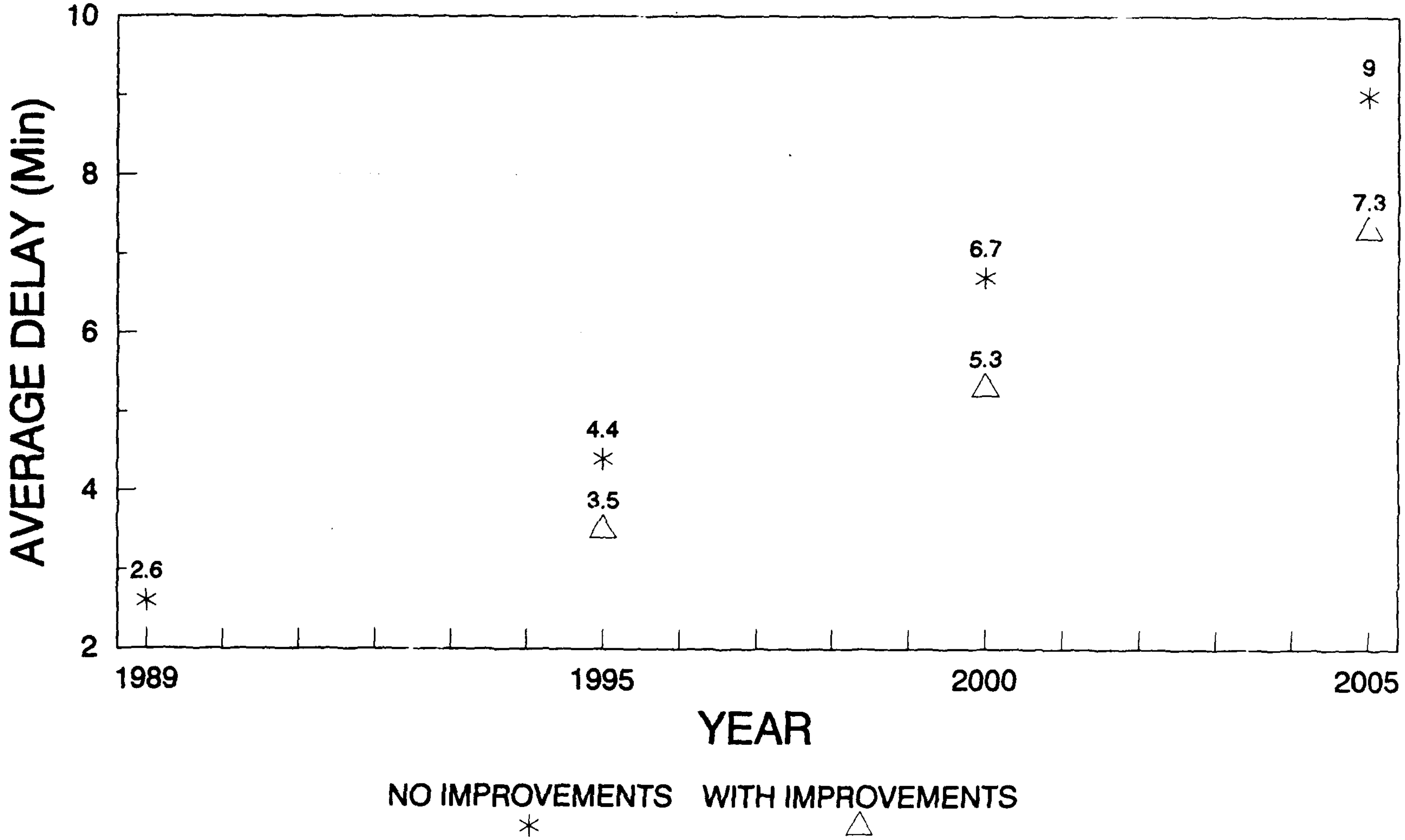



* BL - Baseline, NI - No Imp, D - Delta

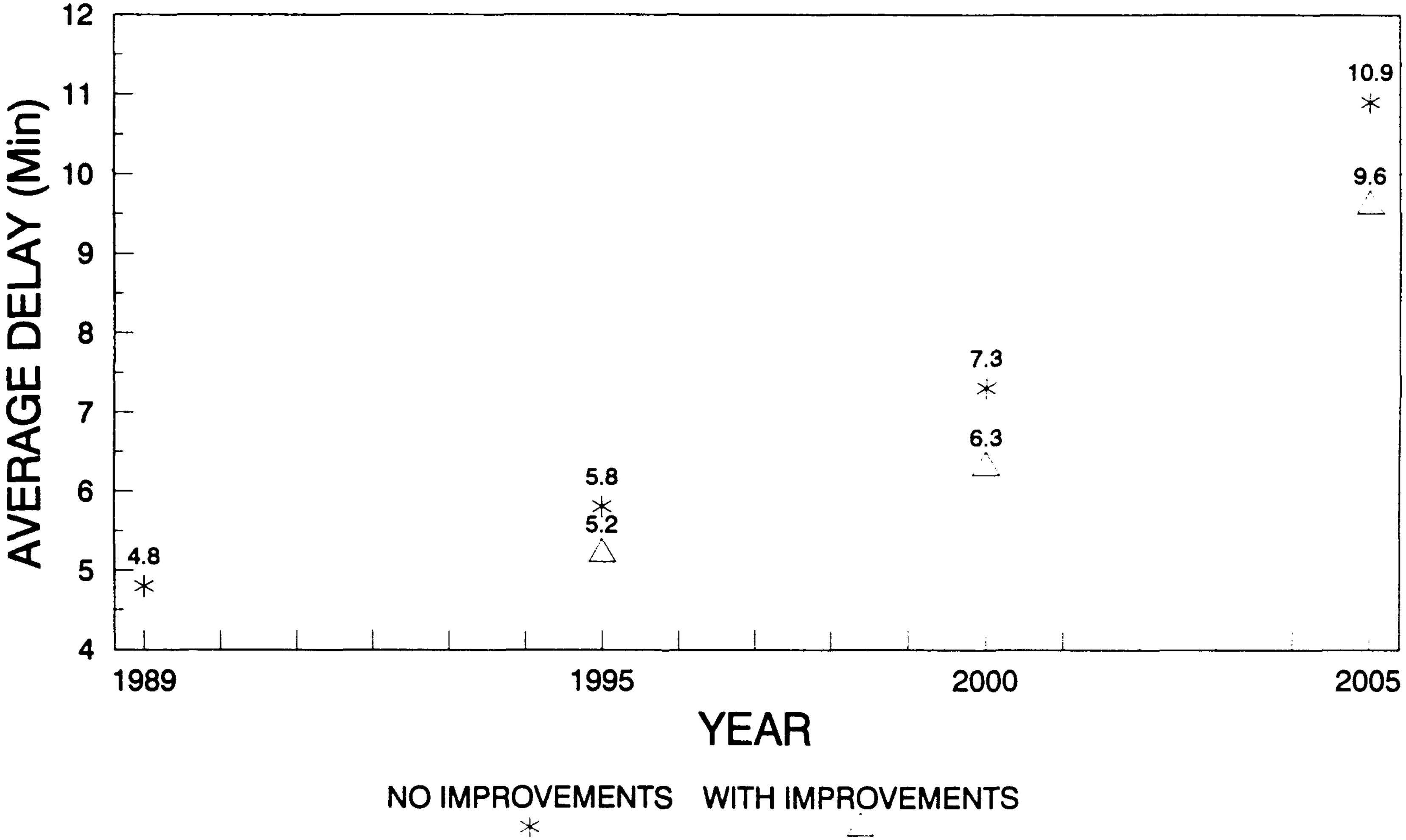
## DAILY AVERAGE MIN. OF OPERATIONAL SYSTEM DELAY
## YEARS : 1989, 1995, 2000, 2005, (March 22, 89)
## VMC (Wx Sys. wide & DFW, near or at max. cap.)



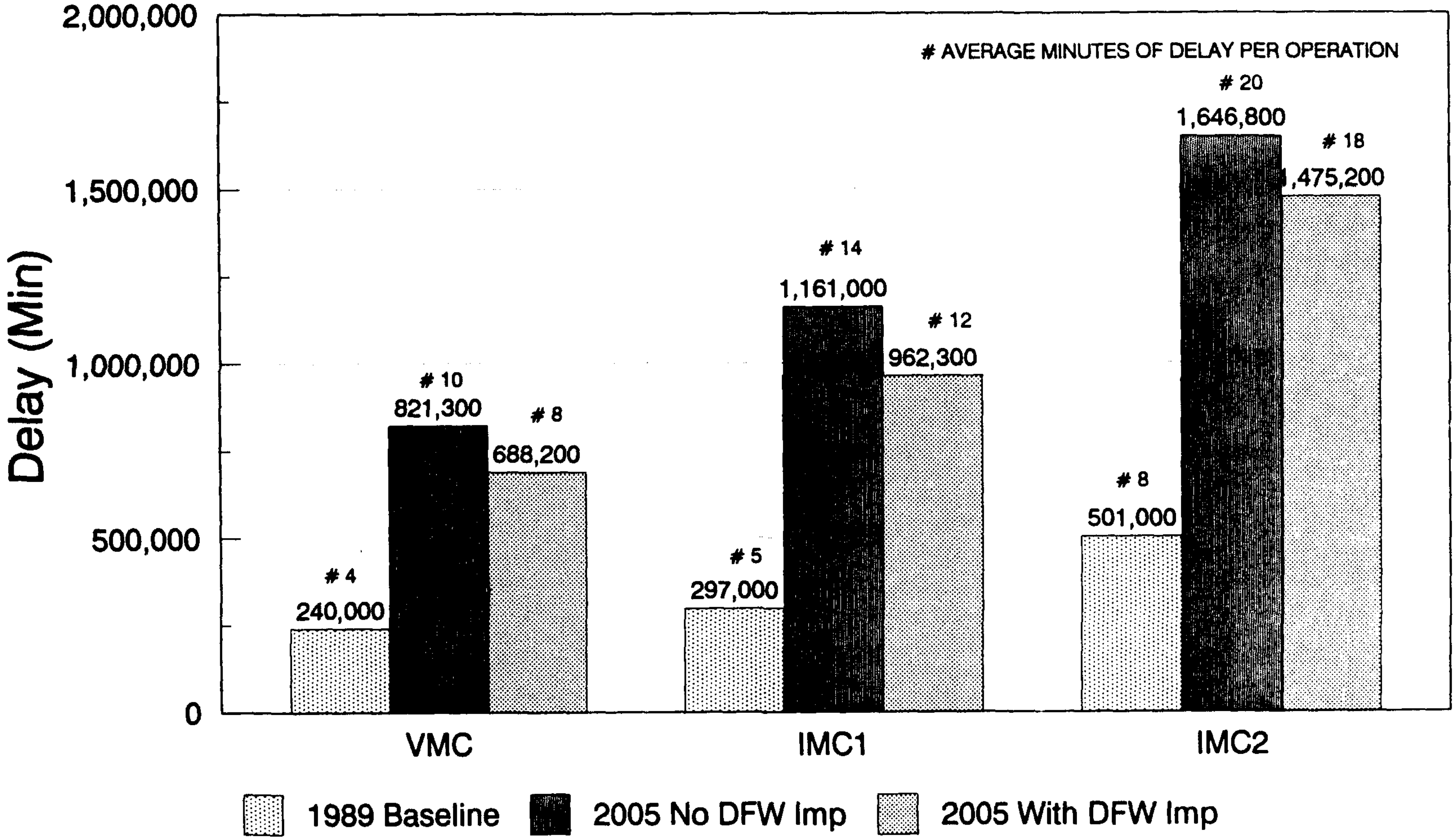
DAILY AVERAGE MIN. OF OPERATIONAL SYSTEM DELAY
YEARS : 1989, 1995, 2000, 2005
IMC1 (17 Hrs of IMC Wx at DFW, February 14, 89)



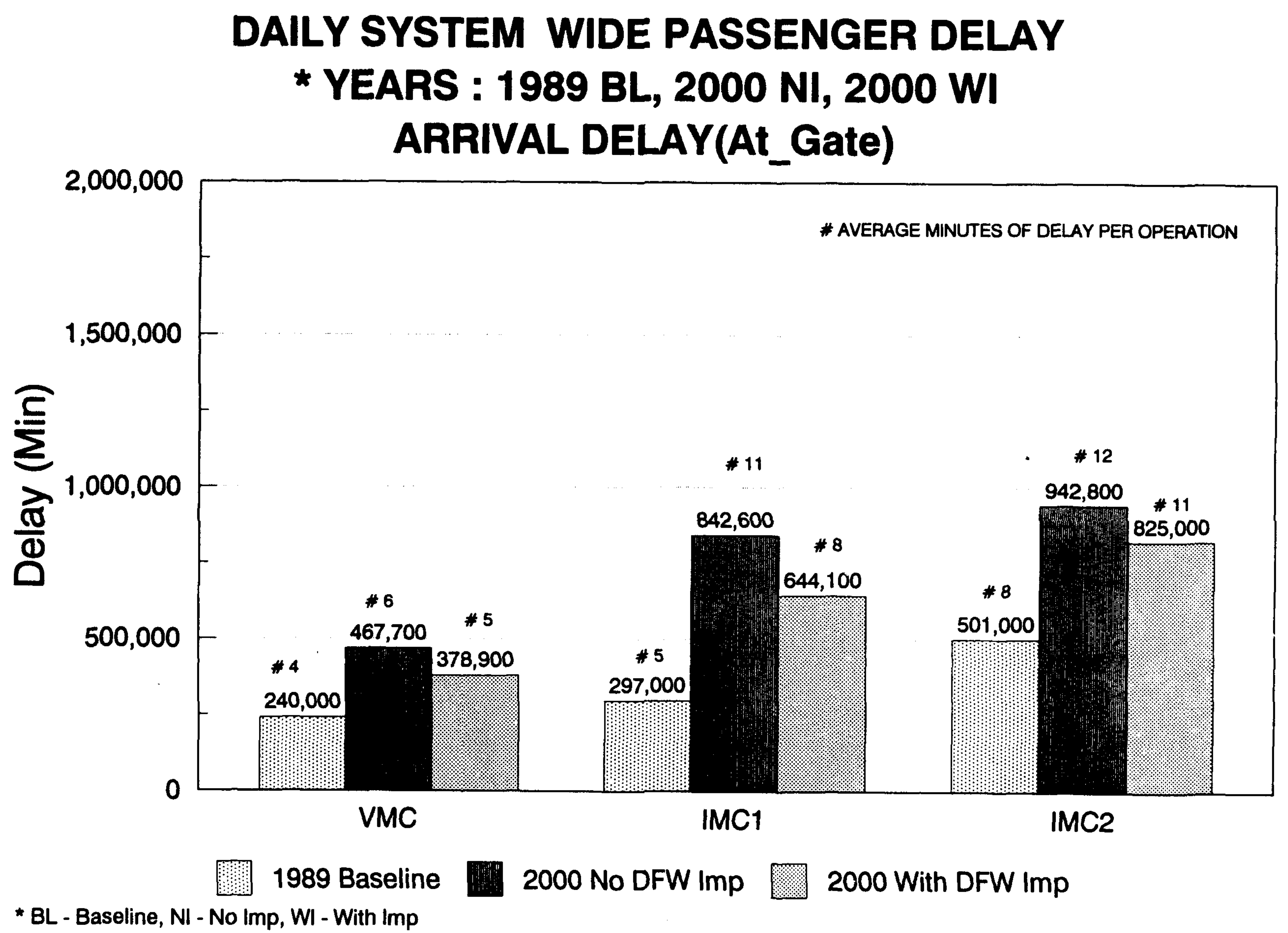
# DAILY AVERAGE MIN. OF OPERATIONAL SYSTEM DELAY
## YEARS : 1989, 1995, 2000, 2005
## IMC2 (6 Hrs of IMC weather at DFW, March 2, 89)



# DAILY SYSTEM WIDE PASSENGER DELAY
# * YEARS : 1989 BL, 2005 NI, 2005 WI
# ARRIVAL DELAY(At_Gate)

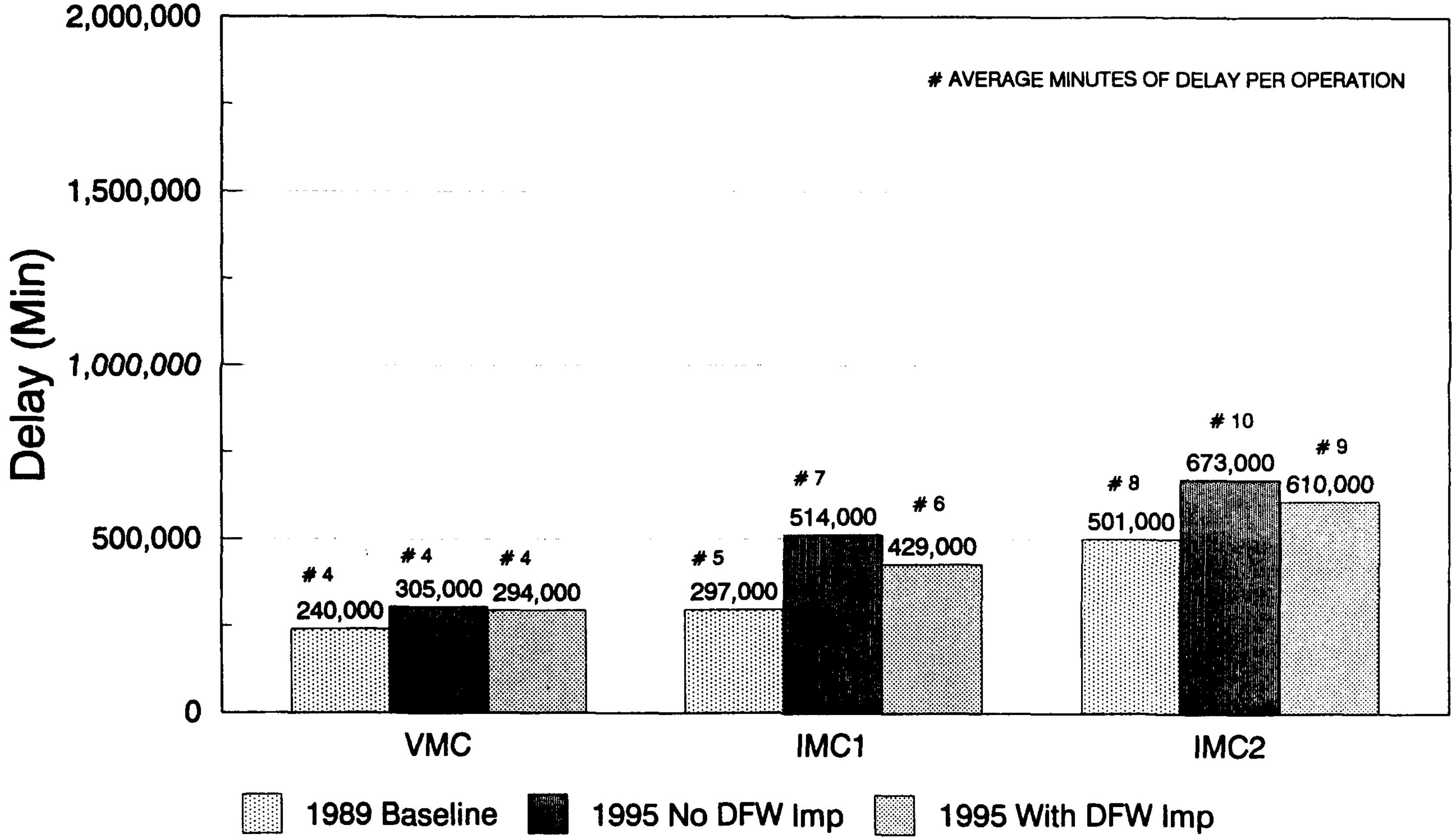



* BL - Baseline, NI - No Imp, WI _ With Imp



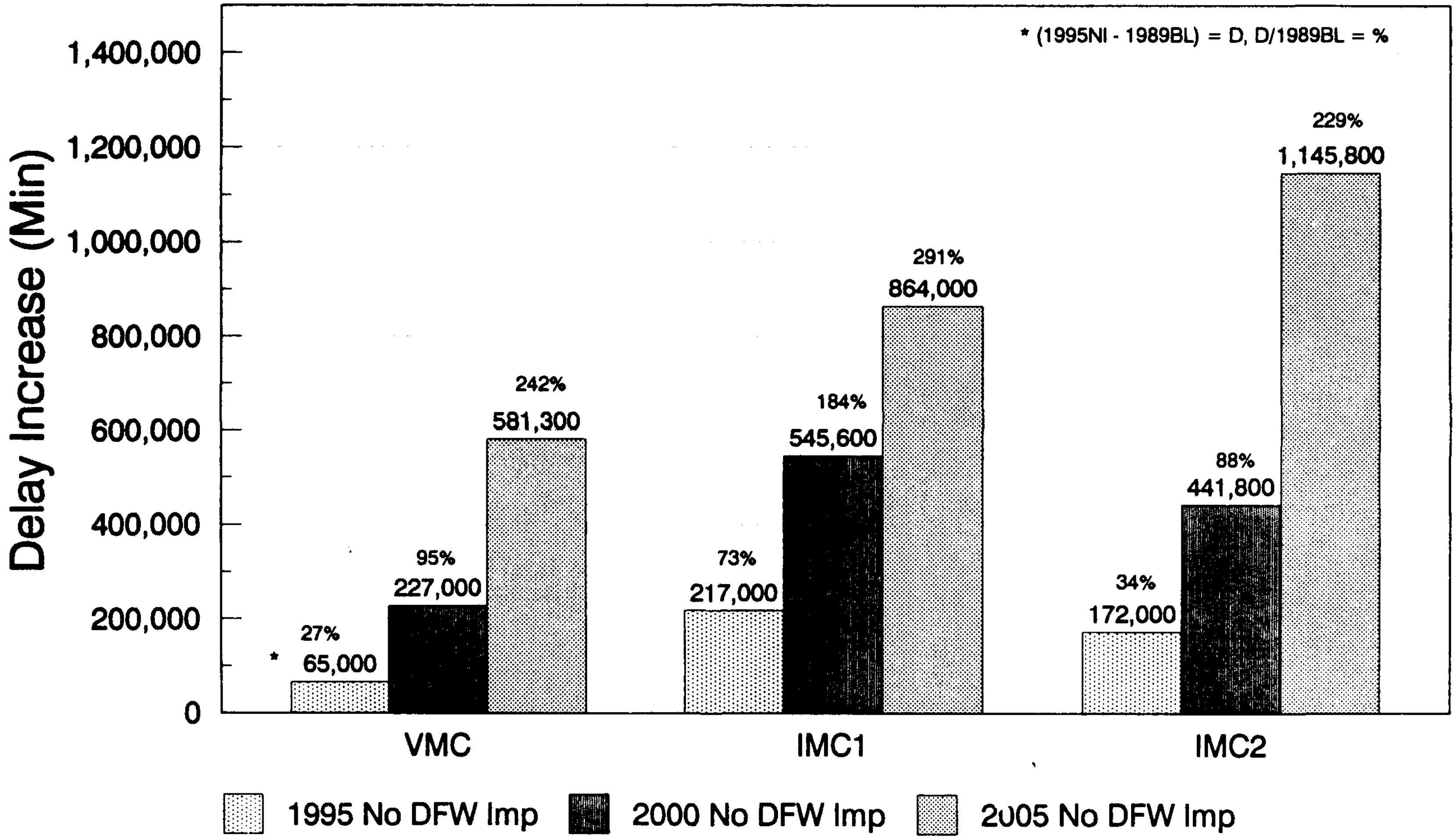
DAILY SYSTEM WIDE PASSENGER DELAY
* YEARS : 1989 BL, 2000 NI, 2000 WI
ARRIVAL DELAY(At_Gate)
Delay (Min)
2,000,000
1,500,000
1,000,000
500,000
0
# AVERAGE MINUTES OF DELAY PER OPERATION
# 4
240,000
# 6
467,700
# 5
378,900
# 5
297,000
# 11
842,600
# 8
644,100
# 8
501,000
# 12
942,800
# 11
825,000
VMC
IMC1
IMC2
1989 Baseline
2000 No DFW Imp
2000 With DFW Imp
* BL - Baseline, NI - No Imp, WI - With Imp

## DAILY SYSTEM WIDE PASSENGER DELAY
## * YEARS : 1989 BL, 1995 NI, 1995 WI
## ARRIVAL DELAY(At_Gate)

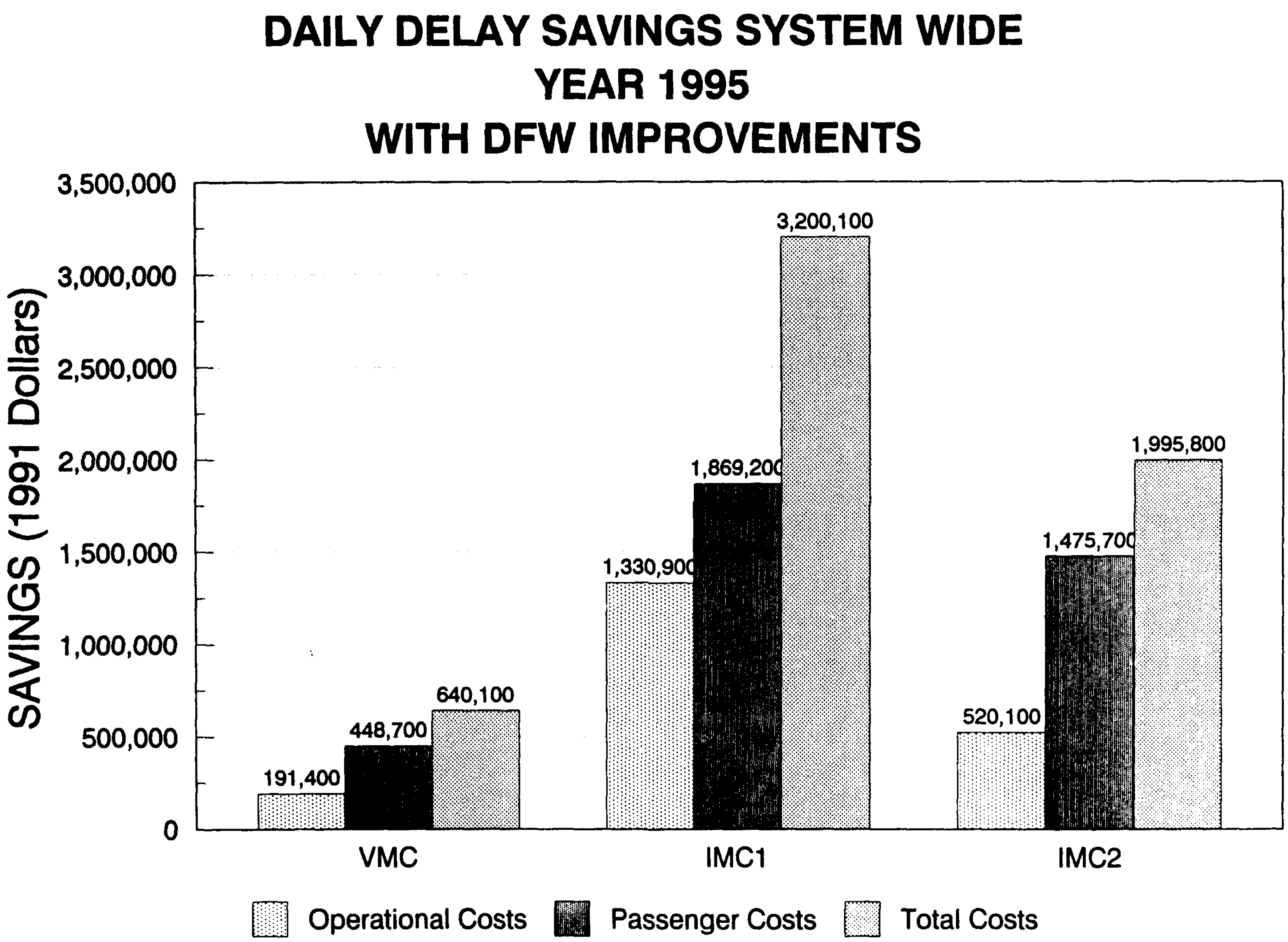


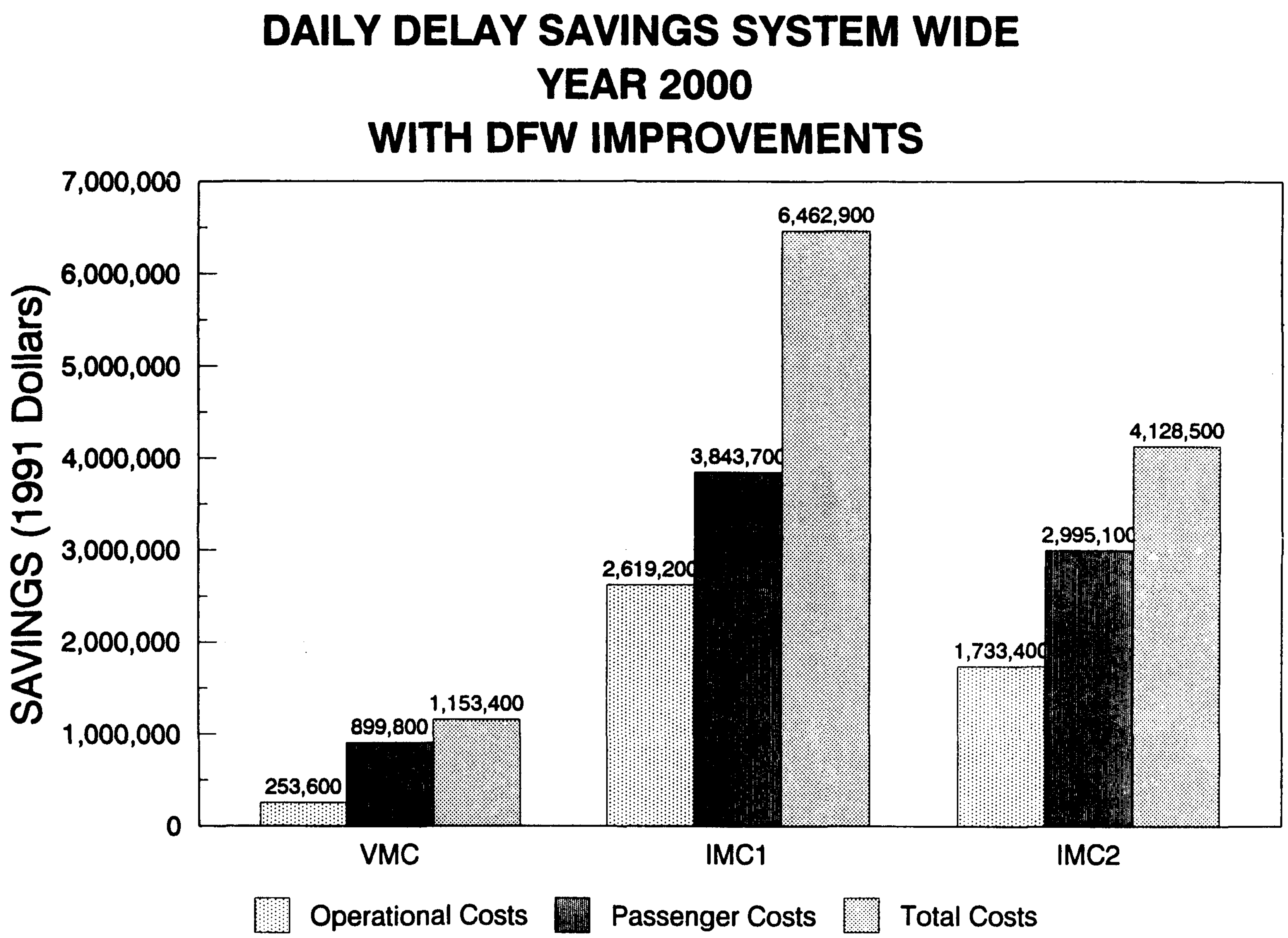

* BL - baseline, NI - No Imp, WI - With Imp

# % INCREASE IN DAILY SYSTEM WIDE PASSENGER DELAY YEARS : 1995, 2000, 2005 WITH NO DFW IMPROVEMENTS

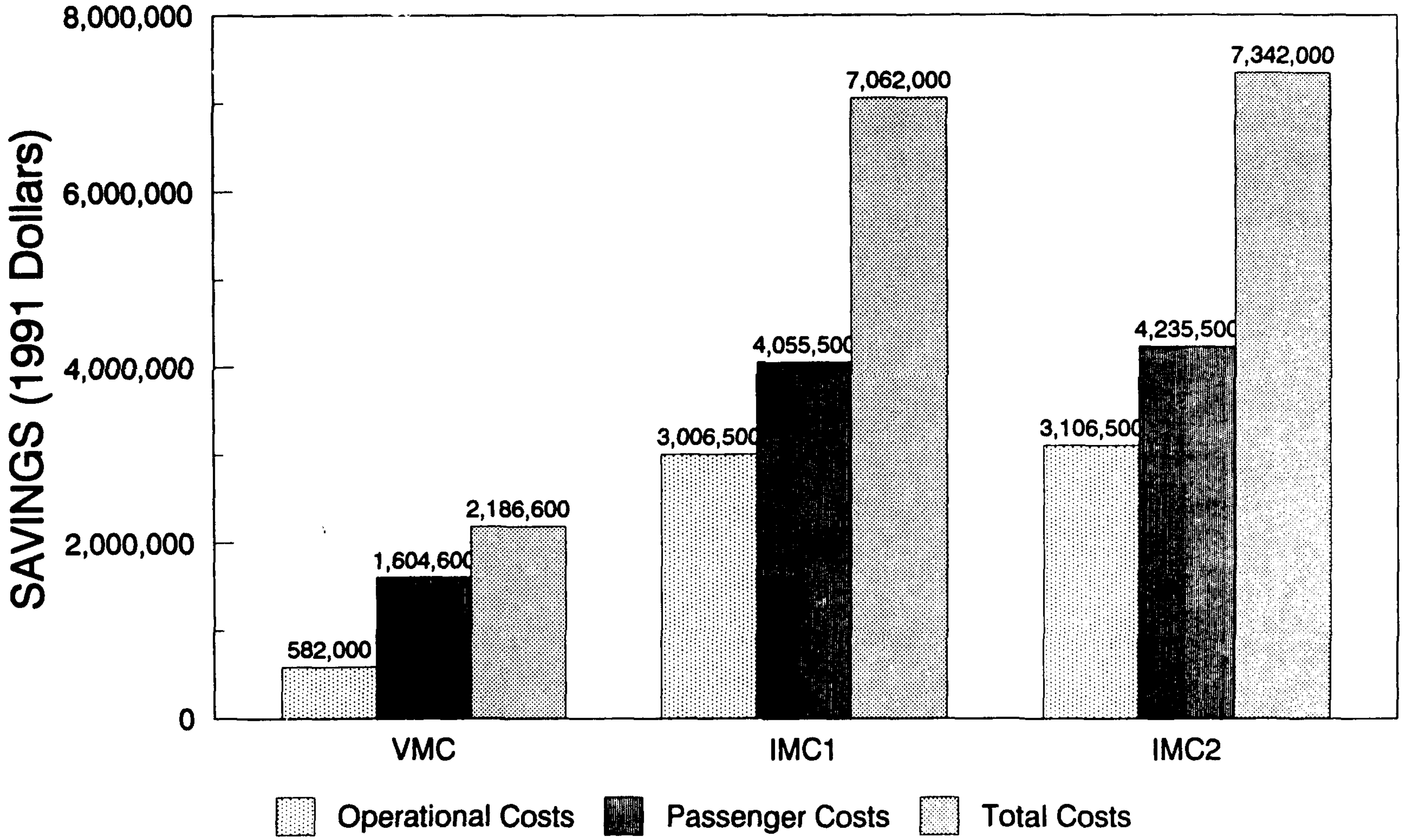



* BL - Baseline, NI - No Imp, D - Delta

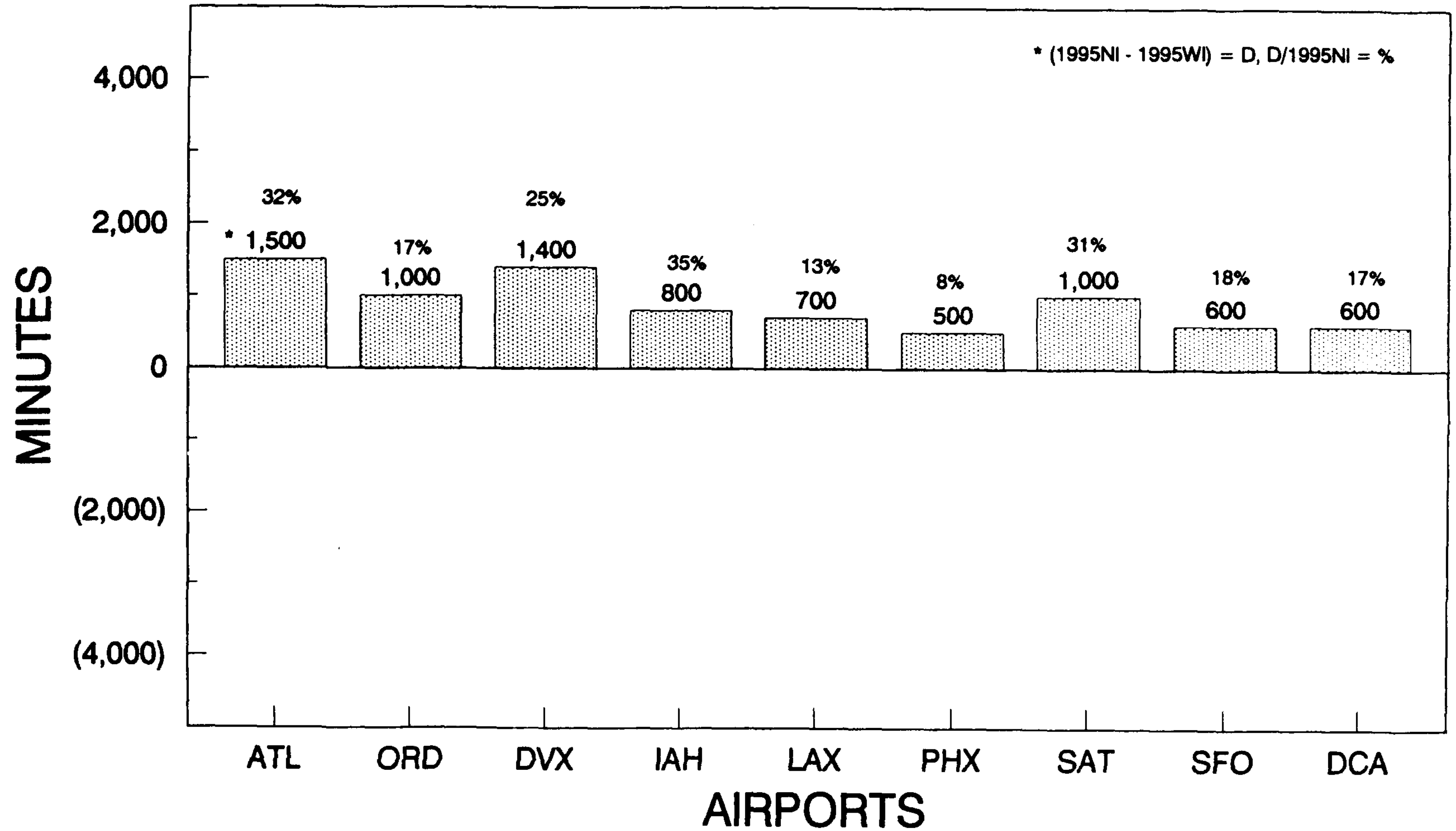

DAILY DELAY SAVINGS SYSTEM WIDE
YEAR 1995
WITH DFW IMPROVEMENTS
SAVINGS (1991 Dollars)
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
191,400
448,700
640,100
1,330,900
1,869,200
3,200,100
520,100
1,475,700
1,995,800
VMC
IMC1
IMC2
Operational Costs
Passenger Costs
Total Costs


DAILY DELAY SAVINGS SYSTEM WIDE
YEAR 2000
WITH DFW IMPROVEMENTS
SAVINGS (1991 Dollars)
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
253,600
899,800
1,153,400
2,619,200
3,843,700
6,462,900
1,733,400
2,995,100
4,128,500
VMC
IMC1
IMC2
Operational Costs
Passenger Costs
Total Costs

## DAILY DELAY SAVINGS SYSTEM WIDE YEAR 2005 WITH DFW IMPROVEMENTS

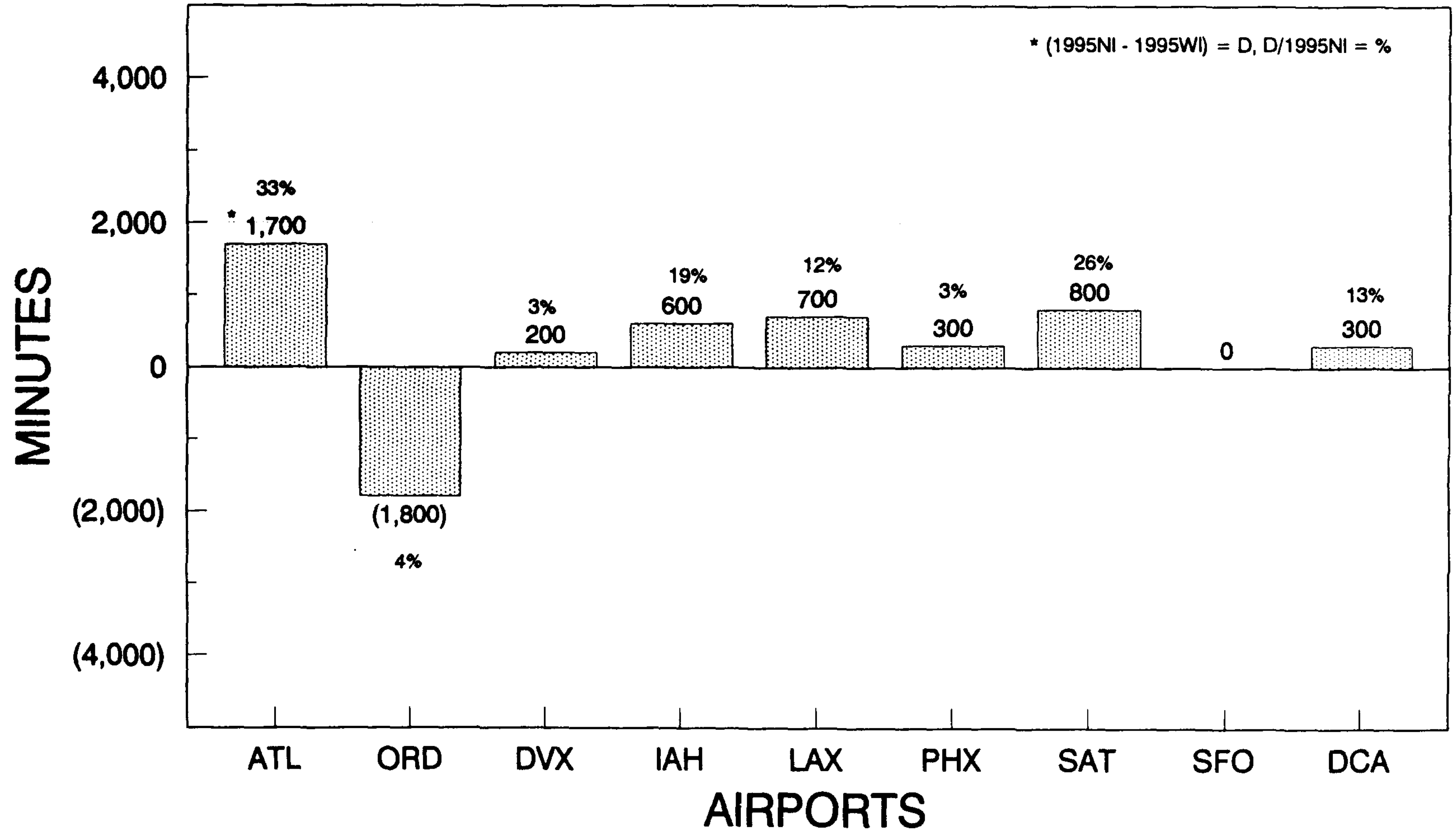


# % DAILY SAVINGS IN PASSENGER DELAY AT AIRPORTS WITH MOST DFW TRAFFIC IN 1995 UNDER IMC1 WITH DFW IMPROVEMENTS



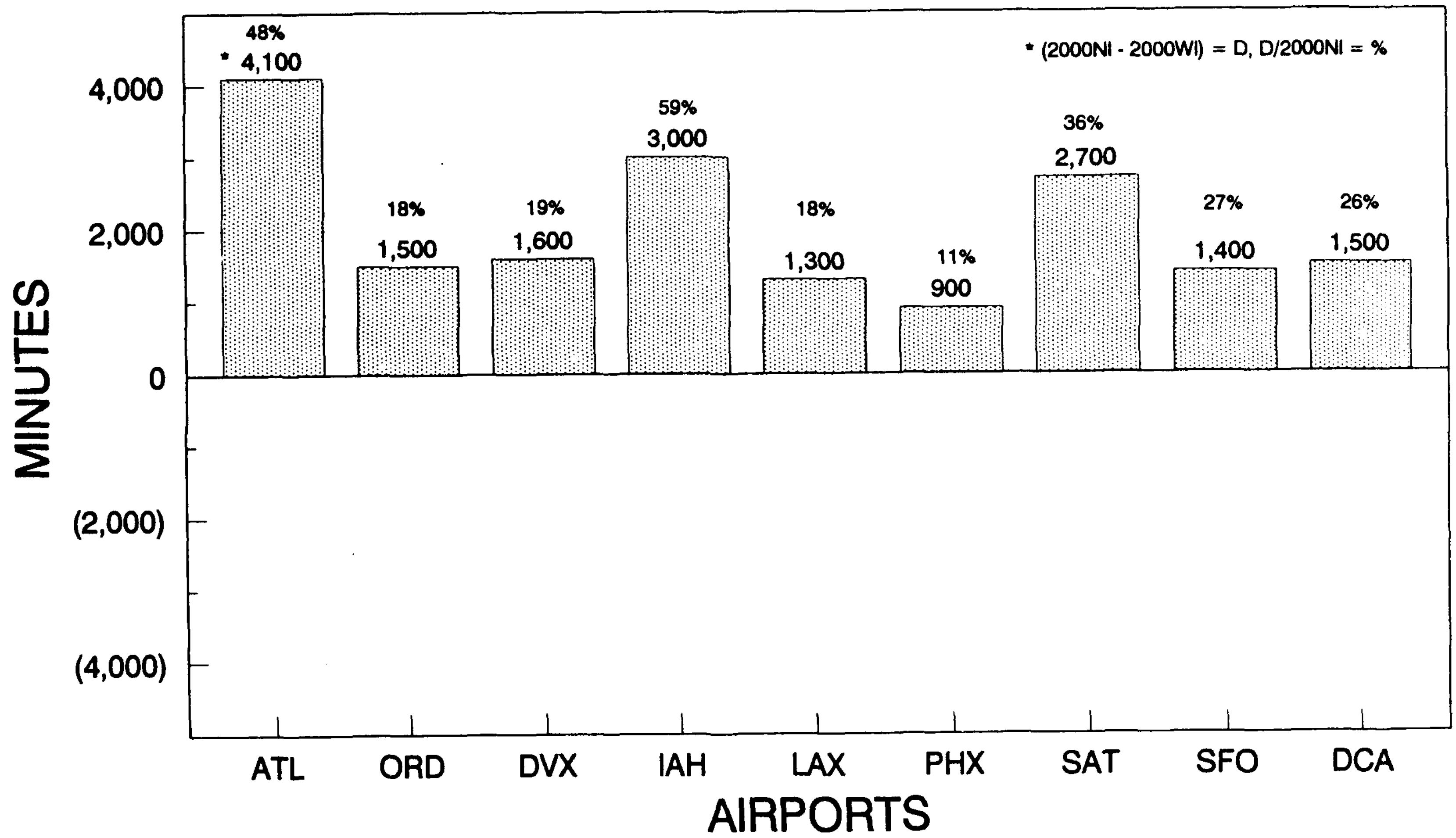

* NI - No Imp, WI - With Imp, D - Delta

# % DAILY SAVINGS IN PASSENGER DELAY AT AIRPORTS WITH MOST DFW TRAFFIC IN 1995 UNDER IMC2 WITH DFW IMPROVEMENTS



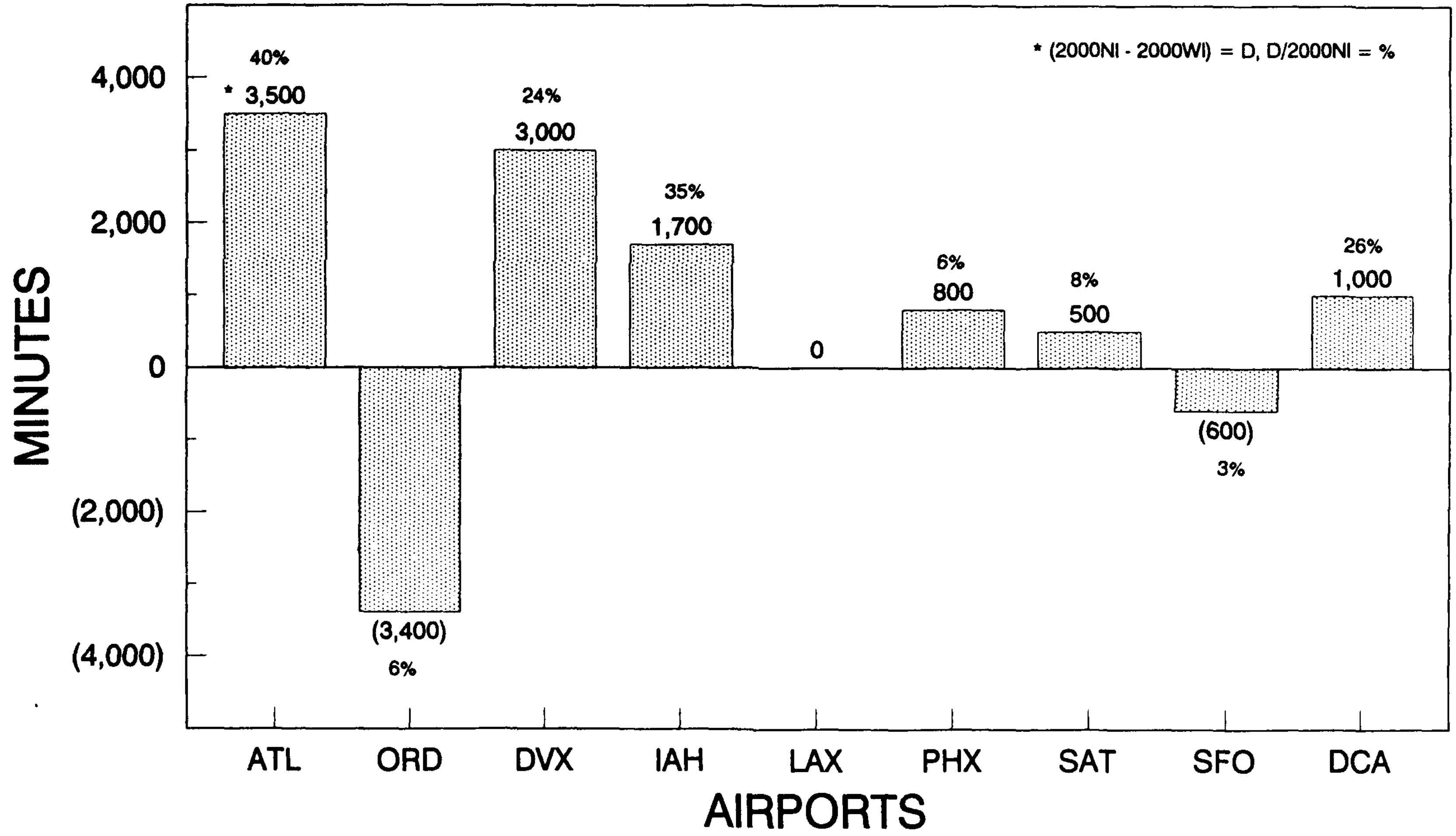

* NI - No Imp, WI - With Imp, D - Delta

# % DAILY SAVINGS IN PASSENGER DELAY AT AIRPORTS WITH MOST DFW TRAFFIC IN 2000 UNDER IMC1 WITH DFW IMPROVEMENTS



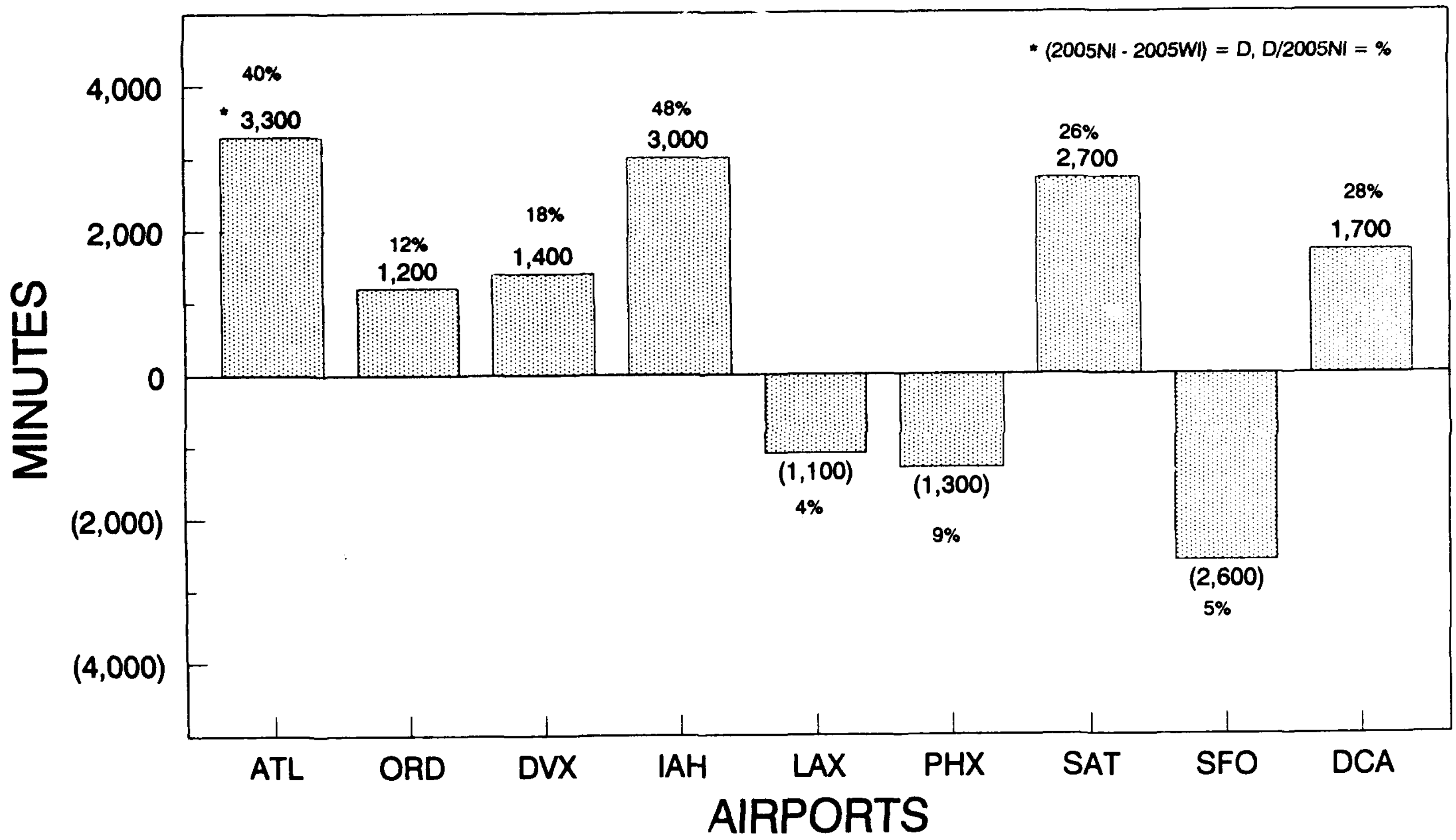

* NI - No Imp, WI - With Imp, D - Delta

## % DAILY SAVINGS IN PASSENGER DELAY AT AIRPORTS WITH MOST DFW TRAFFIC IN 2000 UNDER IMC2 WITH DFW IMPROVEMENTS



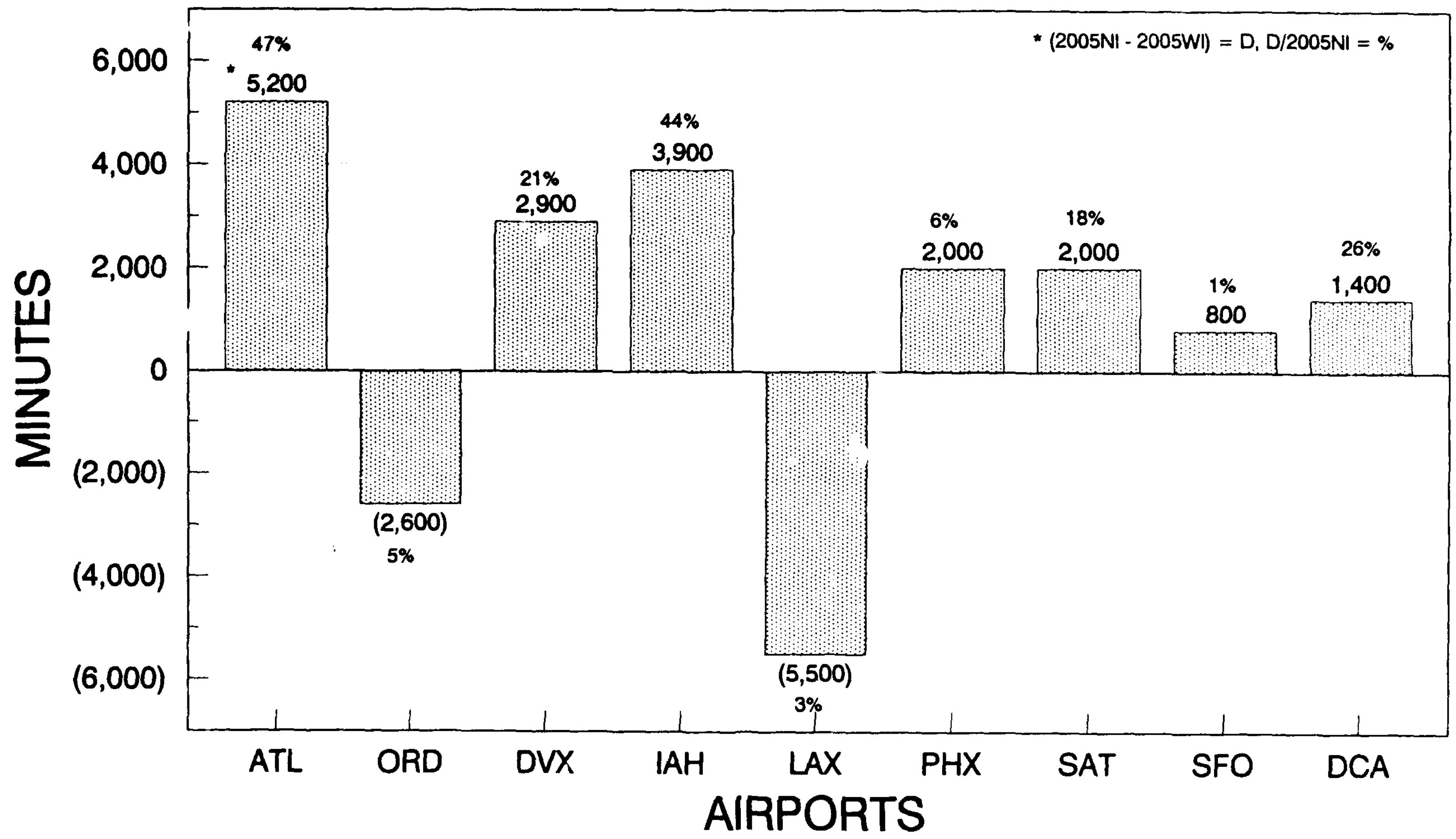

* NI - No Imp, WI - With Imp, D - Delta

## % DAILY SAVINGS IN PASSENGER DELAY AT AIRPORTS WITH MOST DFW TRAFFIC IN 2005 UNDER IMC1 WITH DFW IMPROVEMENTS




* NI - No Imp, WI - With Imp, D - Delta

# % DAILY SAVINGS IN PASSENGER DELAY AT AIRPORTS WITH MOST DFW TRAFFIC IN 2005 UNDER IMC2 WITH DFW IMPROVEMENTS




* NI - No Imp, WI - With Imp, D - Delta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